THE UNIVERSITY OF ALBERTA

THE ARRIVAL PATTERN OF TRICHOPTERA AT ARTIFICIAL LIGHT NEAR MONTREAL, QUEBEC

BY

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "The Arrival Pattern of Trichoptera at Artificial Light near Montreal, Quebec" submitted by Andrew P. Nimmo in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The pattern of arrival of Trichoptera at artificial light is examined at Ile Ste. Hélène, in the St. Lawrence River opposite Montreal, Quebec. Total numbers taken of each of the 78 species found during this study are given, with a breakdown to seasonal sex ratios and female conditions (gravid or non-gravid). Seasonal occurrence is briefly summarized. The pattern in all 7 species examined in detail is nocturnally bimodal, with only a small morning peak. The role of light, temperature, wind, relative hunidity, and saturation deficit in determining total catches per night, and fluctuations of numbers within any one night, are examined. Temperature and wind are the primary factors, with light determining the time of the evening and morning peaks. Sex ratios and ratios of gravid to non-gravid females throughout the night are examined briefly, and it is concluded that no one segment of any of the seven major species is alone responsible for the peaks. Finally, the possibility of the pattern of activity at light reflecting a natural pattern of flight activity is discussed.

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PROLOGUE

"But by the insect world did our little island seem to be most highly appreciated - no limit being placed to their variety and number.

"Every day some new and more horrible species would make its appearance, displaying to our appalled optics a singularly superfluous number of wings and legs. And among this class of the animal kingdom, I have observed that our loathing towards them is always in proportion as their legs exceed the respectable and commonplace number of four. In the hot evenings of a Canadian summer, sitting reading or writing in one's room, the windows were always left open to create a draught. The common way of lighting the apartment was by suspending against the walls paraffin lamps with reflectors attached. The brilliancy of these attracted the insects from all parts of the surrounding darkness, and one would soon hear the buzz and conversation of enterprising individuals rushing wildly to the lamps and destruction. The walls and floor surrounding these lamps would have afforded an interesting field for study to the entomologist, covered as they were with the flattened bodies of every variety of insect, differing in everything save the common penchant for suicide."

F. Duncan (1864), writing of Ile Ste. Hélène.

INTRODUCTION

Ile Ste. Hélène, in the St. Lawrence River opposite Montreal, Que., and adjacent areas of the south bank of the river were, when this study was carried out, being prepared for the 1967 World's Fair, or 'Expo '67'.

Several areas on the St. Lawrence River system often experience vast invasions of 'shadflies', as Trichoptera and Ephemeroptera are collectevely known, notably Fort Erie, Ontario (Munroe, 1951; Peterson, 1952). It was realized therefore, that these insects were, at least potentially, a source of public nuisance at the Fair site. This being so, the 'Shadfly Project' was initiated to determine the exact nature of this potential nuisance, and to investigate possible abatement measures.

Possibly due to the location of the project, only the Trichoptera element of the shadflies was ever taken in numbers suitable for study. Thus the project was concerned only with the Trichoptera.

Several lines of inquiry were followed in the summer of 1964, dealing mainly with the day-by-day biology of the Trichoptera species present for later use in determining control measures, if any.

These insects do not bite and are offensive, if at all, simply by their presence, especially at night when they congregate about artificial lighting fixtures, often in vast numbers. Secondary nuisances arise by invasions (e.g. Fort Erie, Ontario, as above, and areas around Montreal island), and the consequent possibility of allergic reactions in certain

people, possibly due to breathing in of wing hairs.

It has previously been found that, in East Africa (Corbet & Tjønneland, 1955), the numbers of these insects (Trichoptera) at lights vary according to a definite pattern, or patterns, during the night. Williams has worked on this pattern, but mostly on Lepidoptera (e.g. Williams, 1935), and not at all on Trichoptera. The existence of such a pattern may afford control measures of some sort, and the most economical direction of these measures to the most suitable time of night.

Thus, the part of the project with which this study is concerned was an investigation of the arrival pattern of Trichoptera species to artificial light sources at night - do such patterns exist at Ile Ste. Hélène, and if so what form do they take? The reason for this, of course, lies in the fact that the Fair site is to be intensively illuminated at night. The study was carried out with the intention of examining the effects of meteorological factors, including natural light, on the patterns.

While the study deals with the pattern of arrival of Trichoptera at artificial light, and the ensuing results can only be directly interpreted within that particular set of conditions, some attempt will be made in the discussion at the end, to relate the pattern found to natural patterns of activity, independent of artificial stimuli. In view of the possible relationship between the pattern of numbers arriving at light and natural patterns of activity, a short review of recent literature on natural activity rhythms follows.

As stated above, this study deals with activity patterns

at night. But, although daytime activity is not examined, any pattern found within a part of a 24 hour period, if natural, may be taken to be part of a 24 hour pattern, or rhythm, of activity. The use of the term 'rhythm' is not restricted to activity within (approximately) 24 hour periods. Twenty four hour rhythms, as such, may be referred to as 'circadian'or 'diurnal' rhythms (Cloudsley-Thompson, 1961).

The major questions inherent in the study of activity rhythms in nature are: 1). What type of activity rhythms exist?; not with regard to the period of the rhythm but to the persistence of the rhythm when the organism is removed from its natural environment to another where environmental rhythms may vary differently or, as in the laboratory, may be non-existent. 2). What are the origins of these activity rhythms? Are they simply products of the effects of environmental rhythms on the organism, or are they intrinsic to it? (i.e. are they transferable from parent to offspring?) 3). By what method does an organism time activities to produce a pattern? It will be realized that the answer to question 3, in any one case, will largely depend on the answer to questions 1 and 2.

Park (1940) divided activity rhythms of any period into 2 basic types: exogenous - disrupted when environmental conditions are held constant; and endogenous - continuous under constant conditions. Cloudsley-Thompson (1961) concludes that the distinction is really only one of degree, not of kind. He also outlines 3 theories

on the origin and nature of 24 hour rhythms: 1). Entirely environment dependant - time of activity geared to changes of environmental factors. Presumably the rhythm would be disrupted if all possible environmental changes could be eliminated. 2). The rhythm is imprinted by the environment, or the influence of conspecific individuals (e.g. parents). The rhythm would probably continue for some time under constant conditions. 3). The timing of any rhythm is inherited, and is therefore intrinsic to the individual and species. This would be a truly endogenous rhythm.

There are two possible major timing mechanisms of 24 hour rhythms. 1). To quote Cloudsley-Thompson (1961) : "....rhythms of activity in terrestrial animals may be associated with changes in light and darkness, temperature, moisture, food supply, etc.; but of these light intensity is usually the most consistent and reliable." (Harker (1958) examines the effects of these factors in detail). He goes on to point out, though, that light may simply act as a token stimulus, causing the organism to seek out combinations of the other factors more suitable to the conditions of light then prevailing. Park (1931) points out that temperature, visible light, and ultra violet (which Cloudsley-Thompson, (1961) did not mention) are simply three aspects of the same physical category. The division is essentially a human convenience, depending on the method of detection, and it breaks down, to some extent at least, when considering organisms such as insects which can detect ultra violet optically. It will be realized that these 3 factors will follow much the same 24 hour

pattern, and will be in phase with each other. 2). The second mechanism is an internal 'clock' or chronometer. This internal clock, if such exists, is thought to be dependant on the rates of physico-chemical processes within the organism. Just which processes are involved is not definitely known, though there are many possibilities (see Cloudsley-Thompson (1961) and Harker (1958)). Harker (1958) considers that any one organism may have several 'clocks' operating simultaneously on a 24 hour period, though the resulting activities are not necessarily in phase. It is also pointed out that, in insects, the sub-oesophageal ganglion appears to be an integral part of any timing mechanism, but whether it is the basic control or merely an intermediary is not known.

It may be asked, why do these rhythms exist at all? Rhythms which affect activities of an organism, such as flight, movement from A to B to A on a definite repeated schedule, and the like, must be assumed to confer some advantage on the organism involved. Such advantages include the following: protection from predators, either by being asynchronous with the predator activity pattern, or by allowing the prey the advantage of conditions in which it is better able to defend itself; bringing the sexes together, at the proper time and place for mating; feeding, either at such times as food can be found, or to make feeding safer from enemies. These are some basic advantages, but there are many more. More complete expositions of these advantages are given by Cloudsley-Thompson (1961) and Harker (1958).

The natural affinities of the pattern examined here can only be guessed at. Even less can be said concerning the controlling factors or advantages behind the pattern.

METHODS AND EQUIPMENT

INTRODUCTORY REMARKS - To examine patterns of animal activity relative to time, the time involved must be subdivided to a number of equal periods, here called 'catch periods' or just 'periods'. The population at light was sampled during successive fixed units of time. Graphing the numbers taken per catch period will reveal any existing pattern of numbers.

To compare patterns between nights on which trapping was carried out, and obtain meaningful average patterns for the summer, it is necessary to start any one chosen catch period at the same solar time each evening. Two solar times were used, as explained in the following section - sunset (disc of the sun with centre 0.83^{o} below the horizon) and civil twilight (disc of the sun with centre 6^{o} below the horizon). These times, translated to local clock time for each night, were obtained from tables prepared by the Dominion Observatory, Ottawa, and the Meteorology Branch of the Canada Department of Agriculture, Ottawa. The times were prepared for the exact latitude and longitude of Ile Ste. Hélène.

CATCH PERIODS - Strategy on how any existing patterns were to be examined was determined by a trial run on the night of June 2nd., using 2 hr. catch periods starting at 7 p.m. (Eastern Daylight Saving Time). No attempt was made to tie starting time to solar time. The Trichoptera were trapped in a plastic bucket containing 70% ethanol, and surmounted by the vaned cone of a Robinson trap, with the attached light source as described in the following section. The bucket was changed every two hours. The numbers of Trichoptera per catch were as follows: 63/3877/

114/112/31/5. A difinite peak occurred in the second 2 hr. period. No morning peak is evident but, after all catches taken during the summer were counted, it became clear that this is an artifact of the 2 hr. period used, and it is for this reason that the morning peak is not examined in detail.

In the light of these results it was decided to examine the pattern of the entire night using 1 hr. periods, the first of which was to start one half hour prior to sunset, and to examine the evening peak in more detail, using 10 min. periods, one of which was to start at civil twilight. In practice the 7th. 10 min. period was always started on civil twilight, the first 10 min. period thus always starting one hour prior to civil twilight. Civil twilight was used for the 10 min. catches as it was noted after running several 1 hr. sessions that the massive upsurge to the evening peak generally occurred in the second 1 hr. period, in which civil twilight also occurred. It was felt that civil twilight might be of significance to the evening peak of flight activity and the 10 min. sessions were designed to determine the timing and form of the evening peak, and perhaps to determine controlling factors.

The 1 hr. sessions always ran for a total of 12 hrs. as this was the capacity of the automatic trap used, and covered the entire night, ending well past sunrise. As many as 19 ten minute periods were run on some nights, but 13 was decided on as the minimum, which sufficed to cover the period of peak flight activity. One night had only 9 periods due to very cold weather and trapping was stopped early. This night is used in the results, but only when considering catch nights individually

(see appendix C).

TRAPPING (SAMPLING) METHODS & EQUIPMENT

1 HR. CATCHES - The 1 hr. catches were taken with a mechanical trapping device designed and built by Mr. J. LaFrance of the Canada Department of Agriculture Laboratory, St. Jean, Que., and very kindly loaned for this study. No attempt will be made to describe the machine in detail here as Mr. LaFrance proposes to do so elsewhere. Suffice it to say that it is similar in general principles (though not in appearance) to that used by Williams (1935), but less complex. It is capable of hourly changing of catch canisters, though it is possible to adjust it for other period lengths. Capacity is 12 canisters, and the killing agent used was 70% ethanol.

The insects reached the cans by way of a large funnel on top of the trap body, with the spout passing through the roof to the cans below. On top of the funnel was placed the metal cone of a Robinson trap (Robinson and Robinson, 1950), which bears a light bulb socket for an 'Osram' 125 watt, high pressure Mercury vapour light bulb (230-240volts; model MB/V). This bulb is particularly rich in UV light, and is highly attractive to Trichoptera in consequence. A cylindrical collar, 7" high by 13" diameter, made of file-folder card was placed around the upper edge of the Robinson cone after an abortive first use of the trap, in which so many Trichoptera arrived as to swamp the cans and necessitate rejection of the catches for that night. It seemed effective in reducing brilliancy of the light source, and was used for all 1 hr. and 10 min. catches, permitting trapping on some nights on which the abundance of insects

might otherwise have swamped the machine. Even then, the catches which would have been taken on some nights were beyond the capacity of the machine. Intrinsic to the Robinson trap cone are 4 vanes set at 90° to each other, on the inner surface, which serve to stun the insects as they spiral inwards, and downwards, to the light, whence they fall helplessly to the ethanol below. The vanes also serve to hold the collar in place, and hold the light bulb socket. The electrical apparatus accompanying the Robinson trap, for regulation of the current, was retained and temporarily incorporated into the LaFrance trap.

10 MIN. CATCHES - Essentially the same equipment was used to take these, except that the LaFrance trap was not used as such, as it could not be set as low as ten minute intervals. The trap was, however, placed in the usual position and the Robinson cone removed and set beside the funnel, on top of a jar of 70% ethanol - which fitted closely into the bottom of the cone. The cone rested on the top of the jar by virtue of the 4 vanes. The jar was changed manually every ten minutes simply by lifting the cone off the jar and quickly moving a new jar into place, simultaneously pushing the old jar out from under the cone. The LaFrance trap body was used to render the 10 min. catch period conditions as identical as possible to those of the 1 hr. catch periods.

OTHER OBSERVATIONS - All the 1 hr. catch sessions are within that period of the summer in which continuous records of temperature, relative humidity, wind, and rainfall were made, at four points on the island (except that wind recording started after the night of June 13th., on which trapping was first carried out). The records used here are from

what was known as the 'West Station'. This station was only about 20 ft., horizontally, from the edge of the river, but about 50 ft. above the water on a dyke set up for 'Expo 67' purposes. The station was set up and maintained by the Canada Department of Transport.

The following values were extracted for this study, from the records obtained: termperature (^{o}F), and relative humidity were read from the chart at the mid-point of each 1 hr. catch period; wind speed in miles per hour; vapour pressure deficit was obtained from temperature and relative humidity values by use of direct reading tables.

Zenith light readings were taken at the mid-point of each 10 min. period. As time permitted notes on cloud, rainfall and wind were taken. The light readings have since had to be discarded as unreliable for a variety of reasons, rendering the other observations somewhat ineffective as the effect of other factors in conjunction with light were to be examined.

LOCATION OF THE STUDY AND EQUIPMENT - Trapping was carried out at the old Fort on Ile Ste. Hélène, an island in the middle of the St. Lawrence River, between the entrance to the St. Lawrence Seaway to the east, and Montreal Harbour to the west. Fig. 1 shows this, and also the locations of the West Meteorological Station and the trapping site, which are about 50 ft. vertically apart, and ¼ mile horizontally apart. The precise location of the trapping site for 1 hr. and 10 min. catches is given in Fig. 2.

TREATMENT OF CATCHES - Catches were stored in 70% ethanol

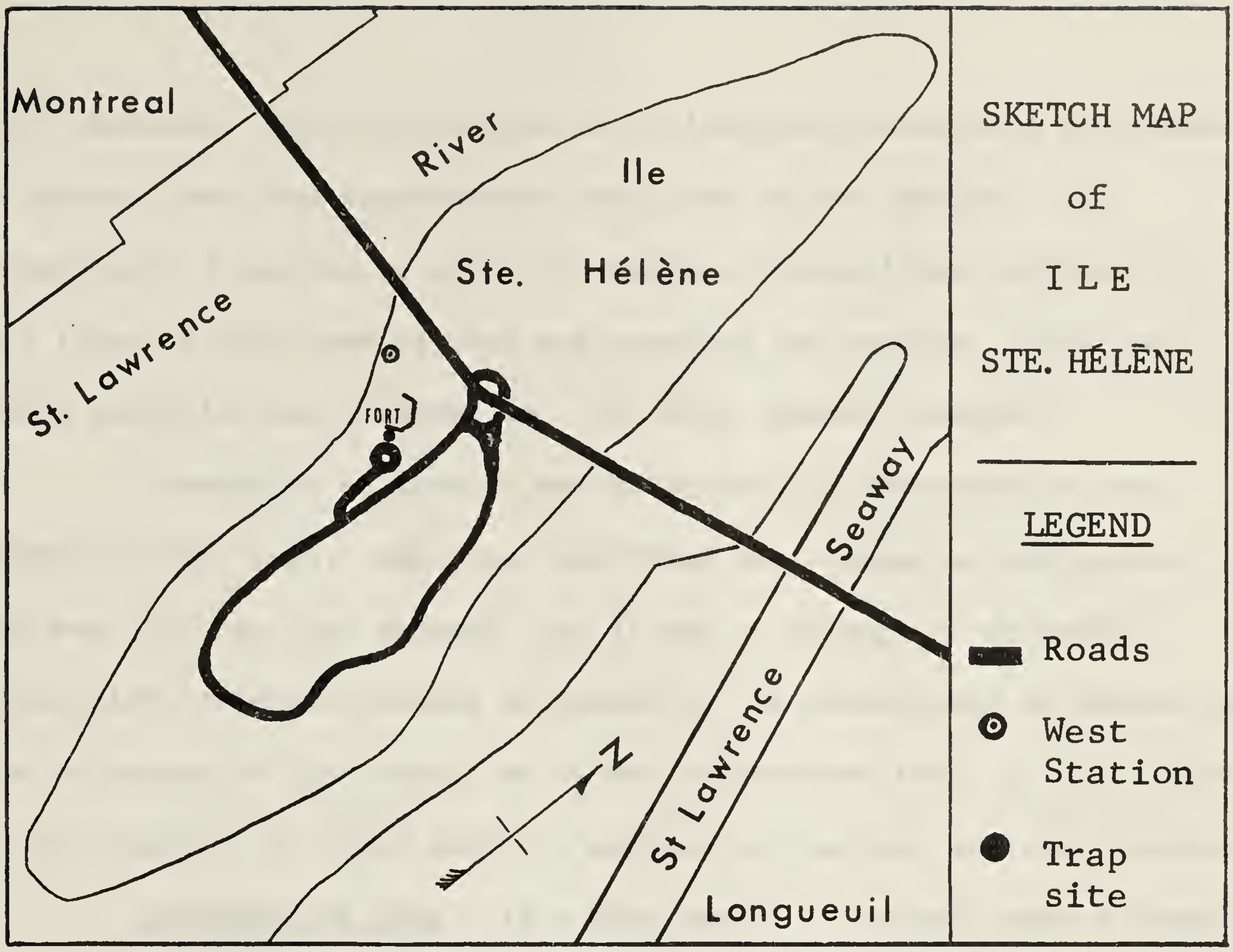


Figure 1

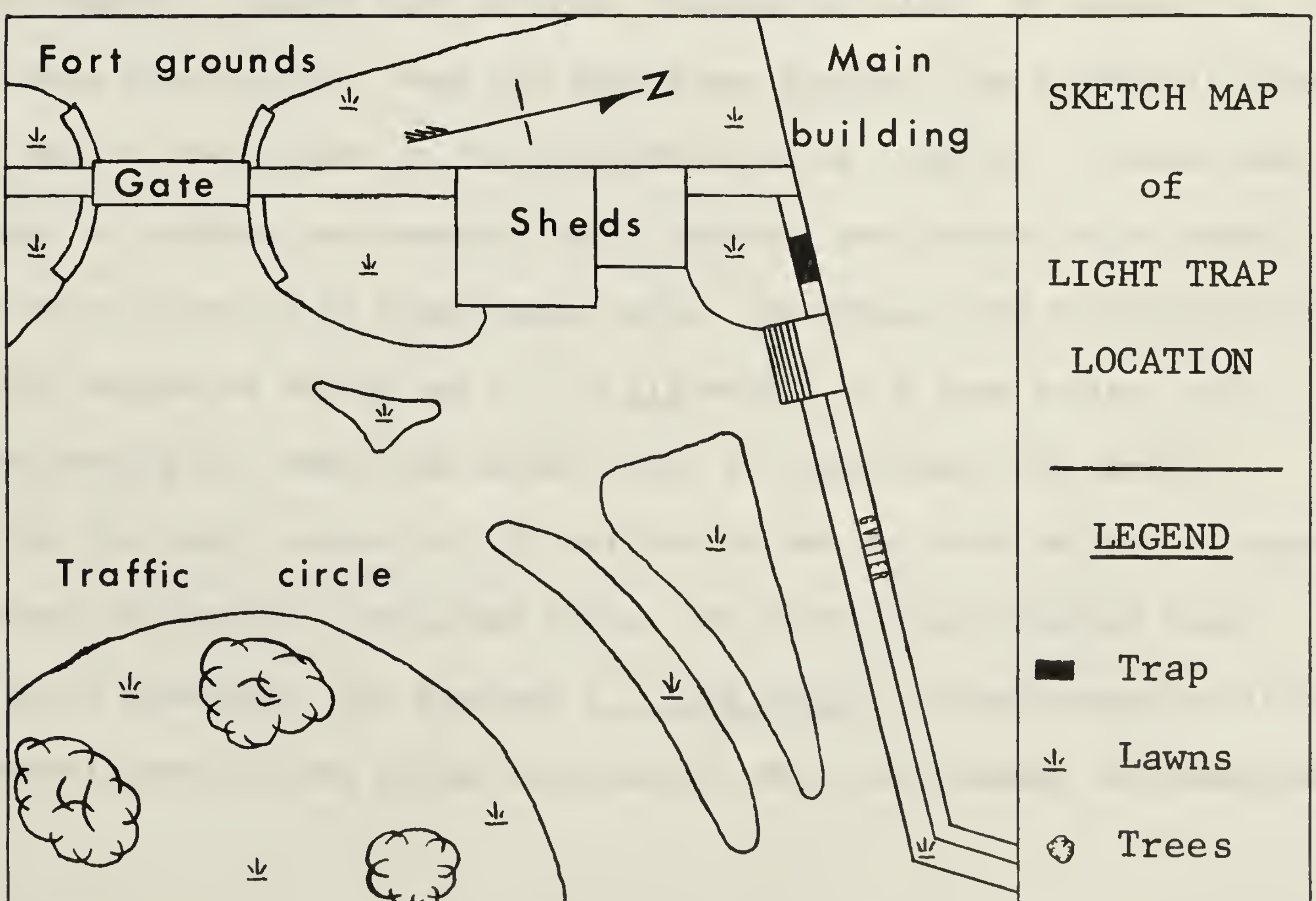


Figure 2

until examined. Most of the time all Trichoptera taken were determined to species, sex, and reproductive condition of the females. But occasionally a species or group of species, Hydroptilidae especially, were taken in such numbers that sub-sampling for species, sexes, and female condition was resorted to. All were counted, however.

Gravidness of females was determined by distension of the abdomen by many eggs. Any other condition was classed as non-gravid. This was all that time allowed, and it was an attempt to determine if any nightly pattern exists at lights in the proportions of females capable of mating or egg-laying, as it was conjectured that, if a definite pattern existed, it might serve to explain any pattern of total numbers.

TREATMENT OF DATA - If a time series of animal numbers shows an intrinsic pattern this pattern will very likely be obscured by extrinsic fluctuations in numbers, from one catch period to the next, due to environmental factors such as wind, fluctuating also. To reduce the effect of these fluctuations, when the values are graphed, the arithmetic values (n) may be transformed to the logarithmic value (log n). In such time series of numbers are examined here, however, zero values often occur, for which there is no logarithmic value. To bypass this difficulty, Williams (1937) suggested adding one (1) to all values in a time series, and transforming the resulting values (n+1) to logarithms (log (n+1)). If the log (n+1) values for all periods of any one time series, or equivalent periods of several time series (hence the fixed solar starting time of catch sessions), are averaged ($\frac{\Sigma \log (n+1)}{N}$), an approximation of the geometric mean of the series is obtained, when the average is transformed to

the arithmetic value. The arithmetic value of this approximation is known as Williams' mean (Haddow, 1959), and is symbolized as M_w. The value $\left(\frac{\Sigma \log (n+1)}{N}\right)$, when obtained for equivalent periods of several time series, and when graphed, results in an <u>average</u> pattern for these time series.

To summarize:

$$\text{Williams' Mean} = M_w = \text{antilog}\left(\frac{\Sigma \log (n+1)}{N}\right) - 1$$

where (n) is the number of individuals taken in a single catch period, and (N) is the number of catch periods used to obtain $\Sigma \log (n+1)$. The values used in graphs here are, therefore: n; log (n+1); and $\frac{\Sigma \log (n+1)}{N}$.

<u>SOURCES OF ERROR</u> - a). No trapping was done on warm, still nights, when the humidity was high, as experience indicated that the LaFrance trap would be swamped by massive catches. Thus no record was obtained of the pattern on such nights. It is most likely identical with the pattern on the nights on which trapping was carried out, but this cannot be definitely stated.

b). Due to use of slightly incorrect sunset tables, starting times of some 1 hr. catch sessions were slightly wrong. While the errors are minor ($\pm$ 3 minutes, maximum), they are listed in Appendix D.

c). The LaFrance trap could be out by two minutes either way. This is intrinsic to the machine, and the error is not cumulative from one period to the next.

<u>SUMMARY OF WORK DONE</u> - The nights on which trapping took place, and other relevant data, are set out in Table 1 (1 hr. catches) and Table 2

TABLE 1

DATES AND TIMING OF 1 HR. CATCHES OF TRICHOPTERA AT ILE STE. HÉLÈNE, MONTREAL DURING THE SUMMER OF 1964

Night	Time[3] (p.m.) of Catch Start	Sunset[1]	Number of Catches	Night	Time (p.m.) of Catch Start	Sunset	Number of Catches
13-14/vi	8.15	8.45	12	18-19/vii	8.09	8.39	12
16-17/vi	8.15	8.45	12	23-24/vii	8.04	8.34	12
17-18.vi	8.15	8.45	12	1- 2/viii	7.54	8.24	12
27-28/vi	8.18	8.48	12	3- 4/viii	7.52	8.22	12
1- 2/vii	8.17	8.47	12	8- 9/viii	7.45	8.15	12
4- 5/vii	8.16	8.46	12	12-13/viii	7.39	8.09	12
6- 7/vii	8.16	8.46	12	19-20/viii	7.25	7.55	11[2]
13-14/vii	8.12	8.42	12	25-26/viii	7.14	7.44	12

1. See source of error p. 14
2. Only 11 (consecutive) catches were taken due to trap malfunction. As it is catch 12 which is missing, this is of no consequence.
3. Eastern Daylight Saving Time

TABLE 2

DATES AND TIMING OF 10 MIN. CATCHES OF TRICHOPTERA AT ILE STE. HÉLÈNE, MONTREAL, DURING THE SUMMER OF 1964

Night	Time[1] (p.m.) of Catch Start	Time (p.m.) of Civil Twilight	No. of Catches	Stop
2- 3/vii	8.24	9.24	19	11.34
7- 8/vii	8.23	9.23	16	11.03
14-15/vii	8.18	9.18	18	11.18
19-20/vii	8.14	9.14	14	10.34
24-25/vii	8.09	9.09	18	11.09
6- 7/viii	7.51	8.51	13	10.01
13-14/viii	7.50	8.50	9	9.20
23-24/viii	7.22	8.22	13	9.23
26-27/viii	7.17	8.17	13	9.27
30-31/viii	7.09	8.09	13	9.19

OTHER CATCHES

2- 3/vi	7.00 p.m. (Trial run, 2 hr. catches)		6	

1. Eastern Daylight Saving Time.

(10 min. catches). As all observations are based on sun time the actual clock times given are of little moment, except in extracting meteorological data. However, all times used here will be Eastern Daylight Saving Time (E. D. T.).

RESULTS

NUMBERS OF SPECIMENS EXAMINED - Table 3 lists the species taken , in descending order of numbers taken per species in all catches, 1 hr. and 10 min. The percentage of the total number of specimens examined, 297,967, is given for each species. The percent values were used to determine the relative importance of each species at the site. A total of 78 species was taken, plus 2 doubtful forms, in 31 genera and 13 families. The following species were selected for detailed examination of data, and are given in order of importance: *Hydroptila spatulata* Morton, *Cheumatopsyche speciosa* (Banks), *Protoptila maculata* (Hagen), *Hydropsyche recurvata* Banks, *Psychomyia flavida* Hagen, *Athripsodes cancellatus* (Betten), and *Athripsodes tarsipunctatus* (Vorhies). *Agraylea multipunctata* Curtis is omitted as the5,229 specimens were taken on 27 of 28 nights, whereas 4,107 *Athripsodes tarsipunctatus* were taken on 18 of 28 nights. Also in table 3, the total numbers per species are broken down to sexes and gravids & non - gravids. Sex ratios are then given, using the formula: No. of ♀ / No. (♂ + ♀) (as defined in Henderson & Henderson, 1960). And finally, the range of dates on which each species was taken are given, concerning which it must be remembered that trapping started on June 2nd.and ended August 31st.

It hardly needs saying that, the lower the number of individuals taken, the less acceptable the sex ratio. Also, the ratios may be artifacts of the trapping method, due to possible differential attraction of the sexes. One remarkable fact emerges from Table 3, however. *P. flavida* shows a sex ratio of virtually one. Two males were taken, but out of 13,015 individuals this is negligible. Marshall (1935) obtained the same result, but cautioned

TABLE 3

A LIST OF SPECIES OF TRICHOPTERA TAKEN AT ILE STE. HÉLÈNE, MONTREAL, IN THE SUMMER OF 1964

IN DESCENDING ORDER OF NUMBERS TAKEN IN BOTH 1 HR. AND 10 MIN. CATCHES

SPECIES	TOTAL	% of Grand total	♂♂	♀♀	Gravid	Non-Gravid	Sex Ratio	Range of dates when taken
Hydroptila spatulata Morton	114,980	38.6	94,220	20,760	19,129	1,631	.18	13 June - 30 August
Cheumatopsyche speciosa (Banks)	54,582	18.3	25,616	28,966	19,171	9,795	.53	13 June - 30 August
Protoptila maculata (Hagen)	50,738	17.0	30,323	20,415	19,236	1,179	.40	19 June - 30 August
Hydropsyche recurvata Banks	32,515	10.9	18,190	13,605	7,990	5,615	.42	2 June - 30 August
Psychomyia flavida Hagen	13,015	4.4	2	13,013	7,942	5,071	1	13 June - 30 August
Athripsodes cancellatus (Betten)	9,951	3.3	7,766	2,185	1,161	1,024	.22	1 July - 26 August
Agraylea multipunctata Curtis	5,229	1.8	2,773	2,456	1,745	711	.47	3 June - 30 August
Athripsodes tarsipunctatus (Vorh.)	4,107	1.4	2,985	1,122	671	451	.27	27 June - 25 August
Cheumatopsyche campyla Ross	2,598	0.9	716	1,882	1,242	640	.72	2 June - 30 August
Hydroptila waskesia Ross	1,598	0.5	1,466	132	108	24	.08	1 July - 20 August
Hydroptila waubesiana Betten	1,182	0.4 =======	817	365	340	25	.31	13 June - 30 August
Glossosoma lividum (Hagen)	897	Total	541	356	211	145	.40	2 June - 30 August
Oecetis inconspicua (Walker)	695	of 3.3%	276	419	159	260	.60	16 June - 30 August
Athripsodes annulicornis (Steph.)	674	to the next	231	443	68	375	.66	2 June - 5 July

Table 3 continued

SPECIES	TOTAL	% of Grand total	♂♂	♀♀	Gravid	Non-Gravid	Sex Ratio	Range of dates when taken
Cheumatopsyche sordida (Hagen)	610	section	185	425	350	75	.70	27 June - 30 August
Hydropsyche morosa Hagen	600		498	102	89	13	.17	2 July - 30 August
Hydropsyche scalaris Hagen	593		294	299	265	34	.50	4 July - 30 August
Hydroptila perdita Morton	577		530	47	41	6	.08	14 June - 30 August
Hydropsyche bifida Banks	440		237	203	163	40	.45	13 June - 25 August
Polycentropus cinereus Hagen	428		311	117	31	86	.27	14 June - 30 August
Neureclipsus crepuscularis (Walker)	341		247	94	54	40	.28	14 June - 30 August
Leptocella candida (Hagen)	325		168	157	117	40	.48	27 July - 30 August
Brachycentrus lateralis (Say)	184		80	104	7	97	.57	2 June - 14 June
Hydropsyche placoda Ross	146		107	39	27	12	.27	13 June - 26 August
Oecetis immobilis (Hagen)	121		31	90	11	79	.74	1 July - 30 August
Athripsodes ancylus (Vorhies)	106	=======	57	49	16	33	.46	27 June - 1 August
Chimarra socia Hagen	96	total of	59	37	34	3	.38	19 June - 30 August
Macronemum zebratum (Hagen)	92	0.23%	59	33	25	8	.36	27 June - 1 August
Athripsodes angustus (Banks)	63	to the next	23	40	23	17	.63	14 July - 8 August

Table 3 continued

SPECIES	TOTAL	% of Grand total	♂♂	♀♀	Gravid	Non-Gravid	Sex Ratio	Range of dates when taken
Mystacides sepulchralis (Walker)	59	section	36	23	12	11	.39	27 June - 30 August
Helicopsyche borealis (Hagen)	50		45	5	2	3	.10	27 June - 3 August
Nyctiophylax vestitus (Hagen)	41		28	13	4	9	.32	28 June - 19 August
Oecetis cinerascens (Hagen)	41		24	17	8	9	.41	2 July - 30 August
Leptocella albida (Walker)	39		24	15	9	6	.38	2 July - 25 August
Hydropsyche walkeri Betten & Mosely	37		27	10	7	3	.27	28 June - 1 August
Hydropsyche bronta Ross	19		12	7	4	3	.37	19 June - 30 August
Athripsodes punctatus (Banks)	19		8	11	6	5	.59	13 July - 1 August
Hydroptila albicornis Hagen	17		16	1	1	-	.06	13 July; 6, 30 Aug.
Athripsodes resurgens (Walker)	14		12	2	1	1	.14	13 June - 19 July
Athripsodes submacula (Walker)	14		10	4	2	2	.29	13 June - 19 July
Triaenodes flavescens Banks	14		1	13	3	10	.93	13 July - 30 August
Triaenodes injusta (Hagen)	12	=========	3	9	3	6	.75	1 July - 7 July
Chimarra obscura (Walker)	9	total of	7	2	2	-	.22	1 July - 19 July
Oecetis avara (Banks)	8	0.0362%	6	2	1	1	.25	6 July - 3 August

Table 3 continued

SPECIES	TOTAL	% of Grand Total	♂♂	♀♀	Gravid	Non-Gravid	Sex ratio	Range of dates when taken
Leptocerus americanus (Banks)	7	to end of	1	6	3	3	.86	2 July - 14 July
Athripsodes alagmus Ross	6	section	6	-	-	-	0	1 & 3 August
Cheumatopsyche analis (Banks)	6		2	4	3	1	.66	27 June & 1 August
Hydroptila hamata Morton	6		4	2	2	-	.33	2, 14 July, 6 Aug.
Triaenodes marginata Sibley	6		3	3	3	-	.50	27 June - 30 August
Oecetis osteni Milne	5		1	4	1	3	.80	13 July,26,30 Aug.
Athripsodes dilutus (Hagen)	4		2	2	1	1	.50	2 June - 5 July
Limnephilus moestus Banks	4		2	2	-	2	.50	14 June & 2 July
Molanna musetta Betten	4		3	1	-	1	.25	5 July
Neotrichia okopa Ross	4		2	2	2	-	.50	7 & 19 July
Athripsodes uvalo Ross	3		2	1	-	1	.33	24 July & 25 August
Cheumatopsyche montrealensis Nimmo	3		3	-	-	-	0	27 June
Molanna sp.	3		-	3	-	3	1	2 & 13 July
Banksiola selina Betten	2		-	2	1	1	1	14 June & 2 July
Hydropsyche sp.	2		-	2	2	-	1	13 June & 8 August

Table 3 continued

SPECIES	TOTAL	% of Grand Total	♂♂	♀♀	Gravid	Non-Gravid	Sex Ratio	Range of dates when taken
Lepidostoma togatum (Hagen)	2	as	2	-	-	-	0	17 June & 2 July
Limnephilus ornatus Banks	2	above	2	-	-	-	0	28 June & 5 July
Limnephilus submonilifer Walker	2		1	1	1	-	.50	17,28 June, 2 July
Neureclipsus validus (Walker)	2		2	-	-	-	0	2, 5 July
Phylocentropus placidus (Banks)	2		2	-	-	-	0	7 July & 12 August
Agapetus hessi Leonard & Leonard	1		1	-	-	-	0	27 June
Anabolia ozburni (Milne)	1		-	1	1	-	1	2 July
Cernotina sp.	1		-	1	1	-	1	19 July
Hydropsyche vexa Ross	1		1	-	-	-	0	14 June
Hydroptila armata Ross	1		1	-	-	-	0	19 July
Hydroptila consimilis Morton	1		1	-	-	-	0	6 August
Hydroptila virgata Ross	1		-	1	1	-	1	7 July
Hydroptila sp.	1		-	1	1	-	1	13 July
Leptocalla exquisita (Walker)	1		-	1	-	1	1	19 August
Limnephilus hyalinus Hagen	1		-	1	1	-	1	2 July

Table 3 continued

SPECIES	TOTAL	% of Grand Total			Gravid	Non-Gravid	Sex Ratio	Range of dates when taken
Neureclipsus bimaculatus (L.)	1	as above	-	1	1	-	1	7 July
Polycentropus nascotius Ross	1		1	-	-	-	0	5 July
Rhyacophila melita Ross	1		1	-	-	-	0	14 June
Setodes oligia (Ross)	1		-	1	-	1	1	7 July
Triaenodes dipsia Ross	1		1	-	-	-	0	1 July
Triaenodes tarda Milne	1		-	1	-	1	1	3 July
GRAND TOTALS	297,967	99.99%	-	-	-	-	-	-

about the possible differential attraction. Ross (1944) does not mention this condition in discussing the species. Betten (1934) states that he had only 2 specimens, females, but that Sibley (1926) took 893, all female. It is not mentioned how Sibley took these. Dr. F. Schmid, who was also on the Shadfly Project, indicated that this seemed to be the normal condition regardless of collecting method. If this is the actual natural ratio, then *P. flavida* must be regarded as essentially parthenogenetic. Crichton (1960) only considers ratios of species with over 100 individuals taken, which is also done here. Only 26 species qualify, as with Crichton, of which 17 had ratios below 0.50. Of these, only 3 are close to equality: *Agraylea multipunctata* (0.47), *Leptocella candida* (0.48) and *Athripsodes ancylus* (0.46). Of the remaining 9 species, 8 have ratios over 0.50, and only 1, *Hydropsyche scalaris* (0.50), shows equality.

PATTERN OF ARRIVAL AT ARTIFICIAL LIGHT - The data will be examined primarily in the form of total numbers of Trichoptera per catch, after which the separate data on the previously selected species will be examined, for both 1 hr. and 10 min. catches. The delineation of species patterns will only be brief as they essentially follow the total numbers patterns. The average pattern for each species, for the summer, will, however, be presented. The 10 min. catches lost much of their value on the discovery that the light readings were useless, but they will serve to tie down more precisely the evening peak. Only 1 hr. catches will be considered relative to weather, as it is impossible to read values accurately from the meteorological charts for intervals as small as 10 minutes.

Arithmetic graphs are presented for summer average patterns, but

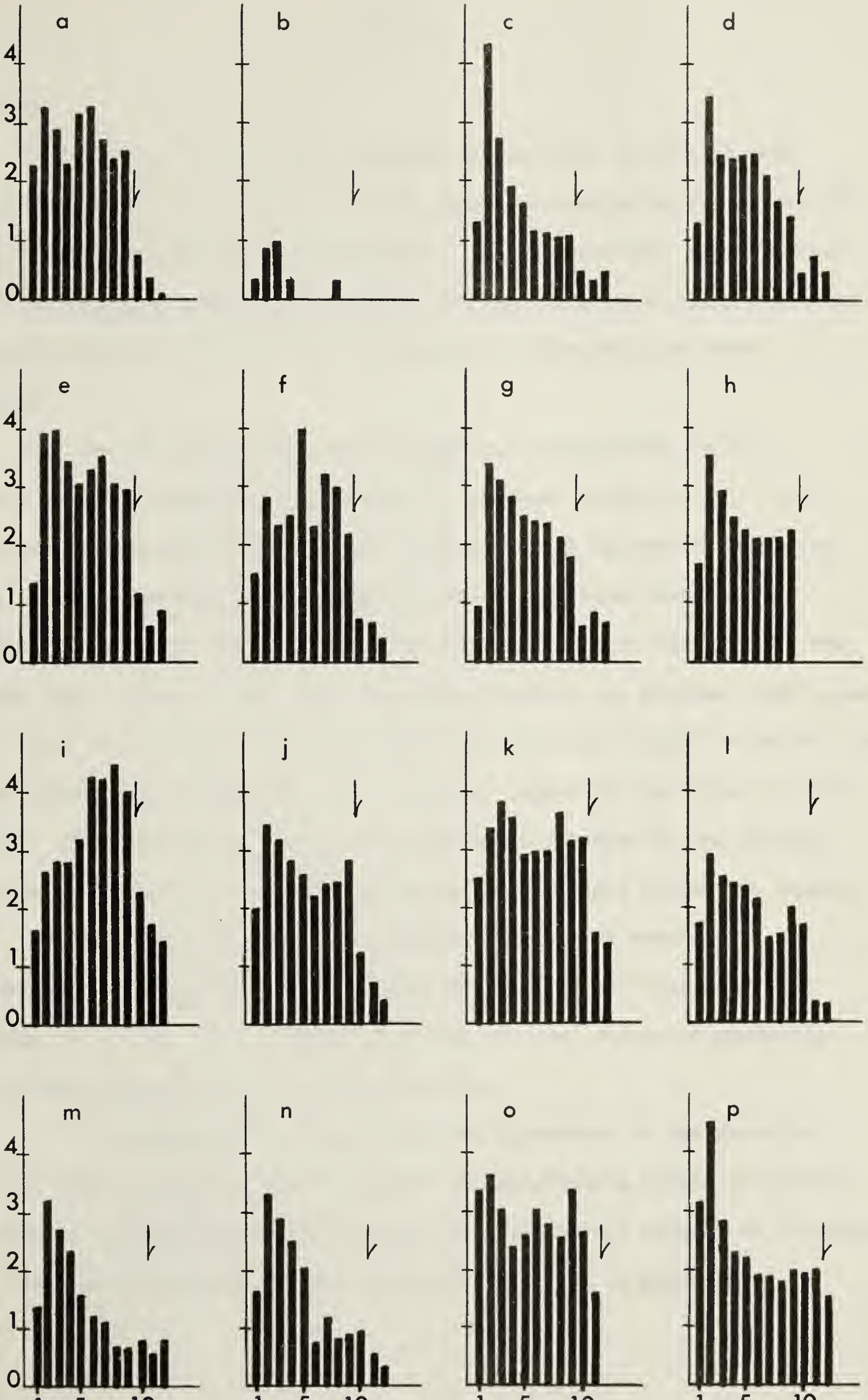
omitted for individual nights. Otherwise, the values used for graphing are as detailed previously: log (n+1) and $\frac{\Sigma \log (n+1)}{N}$.

1 HR. CATCHES

TOTAL NUMBERS PER CATCH - Examining Figs. 3-a....p, it is seen that all but Fig. 3-i show a sudden upsurge after the first catch period and a peak occurs either in the second or third periods, generally the second. In fact, in only 2 of 15 nights did the 'peak' occur in period three, suggesting that this may not be the intrinsic peak, but may be due to extrinsic factors obscuring the peak but permitting the catch of the succeeding period to be of normal volume. One evening (Fig. 3-i) shows no evening peak, which is adequately explained by wind action in the section on 'Effects of other environmental Factors'. Fig. 3 includes arrows indicating sunrise. This is only approximate as the values are plotted at period mid-points and the arrows simply show the two mid-points between which sunrise occurred on any particular morning. The point to note is the shift in sunrise. In most of the figures it is clearly seen that, immediately after sunrise, a sharp dip in numbers occurs. This is obscured in Figs. 3-m and n, probably explainable by meteorological effects, and in Fig. 3-b, probably explainable by a lack of insects due to meteorological factors in more severe form (see 'Effects of other environmental factors'). Figs. 3-o and p provide no opportunity for the sharp drop, due to sunrise being so close to the last period.

In Fig. 3 (all but d....g, and o), a peak, slight or otherwise, is found in the first or second period immediately prior to sunrise. This is the morning peak. In some graphs it does not appear as such and is thought to be masked by preceding catch numbers, due to meteorological

Figure 3 - Graphs of total numbers of Trichoptera taken hourly, at ultra-violet light, at Ile Ste. Hélène, Montreal, for each night on which trapping was carried out during the summer of 1964. Abscissae in 1 hr. periods, log(n + 1) values plotted at the period mid-points ; ordinates in logs. Sunset coincident with the first period mid-point. Sunrise indicated by the arrows. The nights involved are as follows : a) 13-14/vi ; b) 16-17/vi ; c) 17-18/vi ; d) 27-28/vi ; e) 1-2/vii ; f) 4-5/vii ; g) 6-7/vii ; h) 13-14/vii ; i) 18-19/vii ; j) 23-24/vii ; k) 1-2/viii ; l) 3-4/viii ; m) 8-9/viii ; n) 12-13/viii ; o) 19-20/viii ; p) 25-26/viii .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effects.

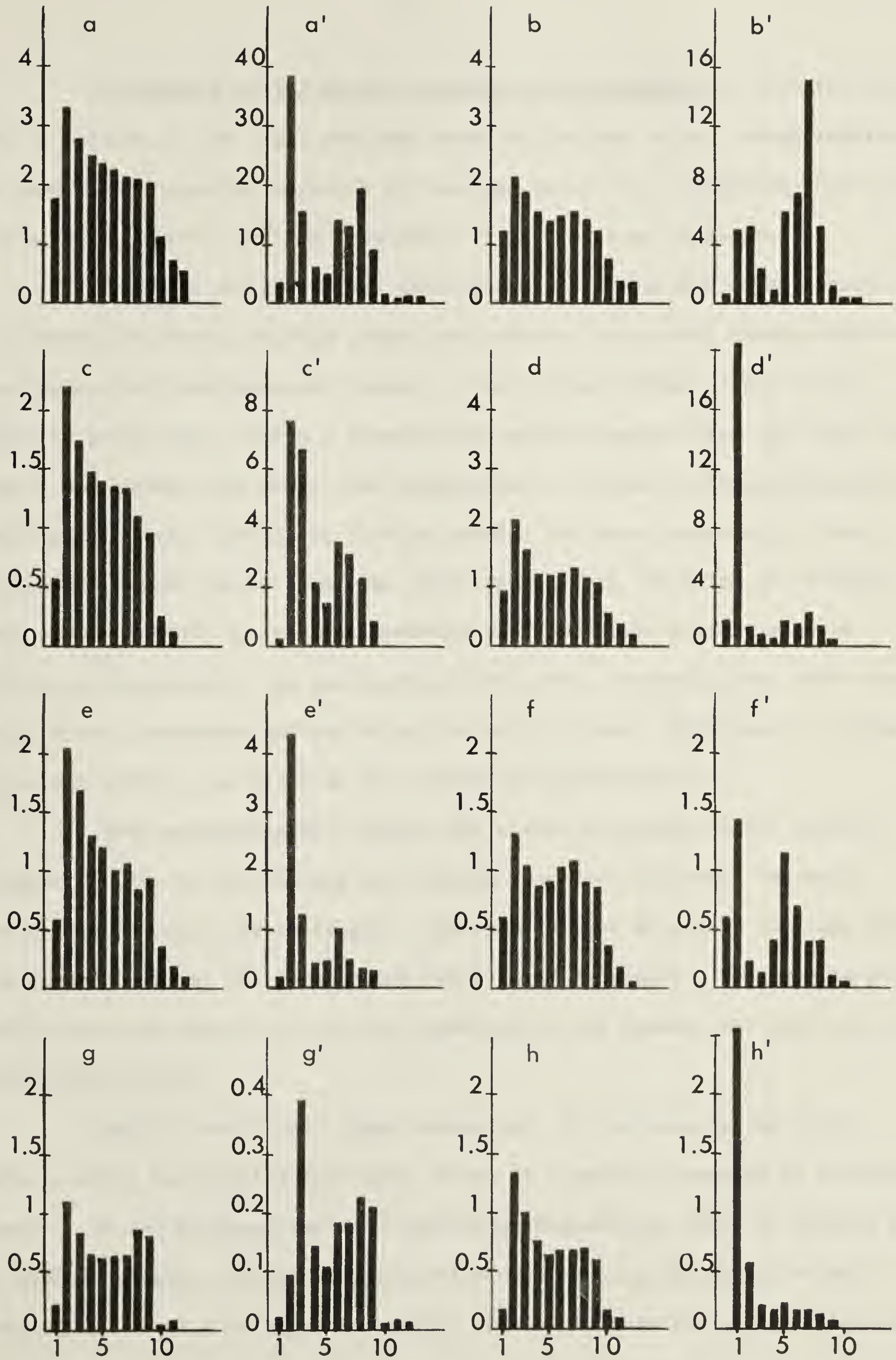
Between the two peaks, evening and morning, it is seen that adults are taken, occasionally in very nicely decreasing series, as in Fig. 3-p, but often in widely varying numbers. It is postulated at this point that the peaks are manifestations of a reaction to natural light intensity of some certain value, with inter-peak activity dependent on other factors.

The average pattern for the summer, as determined by the nights on which trapping was carried out, is shown by Fig. 4-aa'. The distinct evening peak is seen, but the morning peak appears to be absent. This is due to sunrise shift. Starting time of the first catch on any evening is <u>fixed</u> on sunset, and the catch periods are of equal length and number (12). Thus, as the time span between sunset and sunrise varies seasonally, the catch periods are out of phase with natural events which follow sun time, to an extent depending on a) season and, b) length of time from the first period. This results in the morning peak being obscured in the average pattern as it occurs in several different catch periods during the season.

Thus the existence of two peaks, evening and morning, is demonstrated, between which the population may fluctuate but, as shown by Figs. 3 - c, g, h, j, m, and p, and Fig. 4 - aa', tends to gradually, or at least persistently, decline with time.

It remains now to demonstrate the dependance of the peaks on natural light intensity, and to explain the intervening period of gradual decline, or fluctuation as the case may be. The actual numbers of Trichoptera (n) taken in each period of each night will be found in appendix A.

Figure 4 - Average values per 1 hr. period for the entire summer, for total numbers, and 7 species separately, of Trichoptera taken at Ile Ste. Hélène, Montreal, in an ultra-violet light trap on 16 nights, 1964. a-graphs compiled using $\frac{\Sigma \log(n+1)}{N}$ values, and a'-graphs using arithmetic means, etc. Abscissae in 1 hr. periods, values plotted at the period mid-points ; ordinates either in logs or hundreds, as set out above. Sunset coincident with the first period mid-point. The species involved are as follows : a-a') Total numbers for the summer ; b-b') *Hydroptila spatulata* ; c-c') *Cheumatopsyche speciosa* ; d-d') *Protoptila maculata* ; e-e') *Hydropsyche recurvata* ; f-f') *Psychomyia flavida* ; g-g') *Athripsodes cancellatus* ; h-h') *Athripsodes tarsipunctatus* .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10

DEPENDANCE OF THE PEAKS ON NATURAL LIGHT INTENSITY - Unfortunately, due to failure of the light readings taken during the 10 min. catch sessions, an essentially negative approach is required here; i.e., eliminate those factors which do not affect, and the remainder, if any, must be implicated.

Assuming the preceding description of the pattern to be correct, the least fluctuating nightly graphs are selected for visual examination of the concomitant environmental factors. These graphs (Figs. 3-c,h, and p) show the peaks well. Table 4 presents the meteorological data for these three nights and examination shows that temperature is either declining throughout the night, usually slowly, or holding steady, but never increasing. Next, wind holds steady for at least the first two periods, in which the evening peak occurs. Finally, relative humidity and saturation deficit seem to fluctuate erratically. On the night of 13-14/vii, however, they held steady for 5 hours preceeding and including the morning peak. This seems to eliminate these two factors, at least at the values encountered here.

Thus meteorological factors are either declining fairly evenly, holding steady, or fluctuating and showing no correlation with log(n+1), yet the peaks occur outstandingly. The evening peak occurs in the same period, the second, due to the first catch being fixed on sunset. The morning peak may occur in periods 9, 10, of 11, depending on the season, but always in the pre-sunrise period.

Table 4 omits only light intensity. In the evening, with all other factors essentially declining, there is a peak in numbers of Trichoptera caught. In the morning, the same conditions prevailing, there is another peak in numbers caught. The only factor which will have equal values in both evening and morning is light intensity. Obviously from the graphs, the light

TABLE 4

METEOROLOGICAL DATA AND TOTAL NUMBERS OF TRICHOPTERA TAKEN (AS LOG (n+1) VALUES), PER 1 HR. PERIOD AT ILE STE. HÉLÈNE, MONTREAL, FOR THREE SELECTED EVENINGS, SUMMER 1964

Period	log (n+1)	T°F	Wind mph.	* R.H.	** S.D.	log (n+1)	T°F	Wind mph.	R.H.	S.D.	log (n+1)	T°F	Wind mph.	R.H.	S.D.
1	1.30	63.5	6	29	0.42	1.62	71.0	2	85	0.11	3.14	73.0	9	58	0.34
2	4.40	63.0	7	32	0.39	3.51	70.0	1	82	0.13	4.45	69.0	9	60	0.28
3	2.79	62.0	7	36	0.36	2.89	69.5	3	81	0.14	2.76	67.0	19	54	0.30
4	1.89	61.0	7	39	0.33	2.42	69.5	3	84	0.12	2.21	67.0	19	70	0.20
5	1.65	60.0	9	42	0.30	2.25	69.0	2	89	0.08	2.15	67.0	18	76	0.16
6	1.18	60.0	8	46	0.28	2.09	68.5	2	88	0.08	1.81	67.0	15	79	0.14
7	1.14	60.0	8	47	0.27	2.09	68.0	2	88	0.08	1.77	67.0	14	79	0.14
8	1.04	59.0	10	49	0.25	2.08	68.0	2	88	0.08	1.74	66.0	15	76	0.15
9	1.11	60.0	9	50	0.26	2.21	68.0	1	88	0.08	1.91	65.0	14	71	0.18
10											1.85	64.0	14	72	0.17
11											1.98	63.0	13	72	0.17
12															

* R.H. = relative humidity.

** S.D. = saturation deficit, in inches of mercury.

Periods 10....12, or 12, as the case may be, are ommitted as the post sunrise periods are of no interest here.

values involved occur after and before sunset and sunrise respectively. (See the section of these results dealing with the 10 min. catches, for a more exact timing of the evening peak). Thus the causal (or triggering) factor of both peaks appear to be a certain light intensity.

But, assuming for the moment that the pattern at artificial light reflects a natural pattern, what factors influence the pattern between the peaks: Not sunlight, certainly. Celestial light sources other than the sun may play a part; the moon especially. City lighting when reflected from low cloud, also. The light readings, if they had been acceptable, may have provided an answer to the nighttime effects of light other than that of the sun. The Mercury vapour bulb of the trap is a constant light source, and the 'ideal' pattern between the peaks seems to be a gradually decreasing decline, which is hardly consistent with a constant light source. Remembering the pattern of meteorological factors during the night, it may be concluded that one or more of these is correlated with the'ideal' decline. Or, put differently, the fluctuations noted between the peaks of the not-so-ideal graphs may be correlated with deviations from the ' normal ' in the environmental factors.

EFFECTS OF OTHER ENVIRONMENTAL FACTORS

THE NIGHT AS A WHOLE - Examined here are those periods of each night between and including sunset and sunrise. Those morning periods after sunrise are omitted as they have no place in the pattern as set out here.

Means of each factor were obtained for each night: temperature, wind, relative humidity and saturation deficit. Each factor was then plotted against the $\frac{\Sigma \log(n+1)}{N}$ values for each night. Except for temperature, no factor showed any significant correlation with $\frac{\Sigma \log(n+1)}{N}$. As seen in Fig. 5, temperature and $\frac{\Sigma \log(n+1)}{N}$ are clearly correlated to some extent.

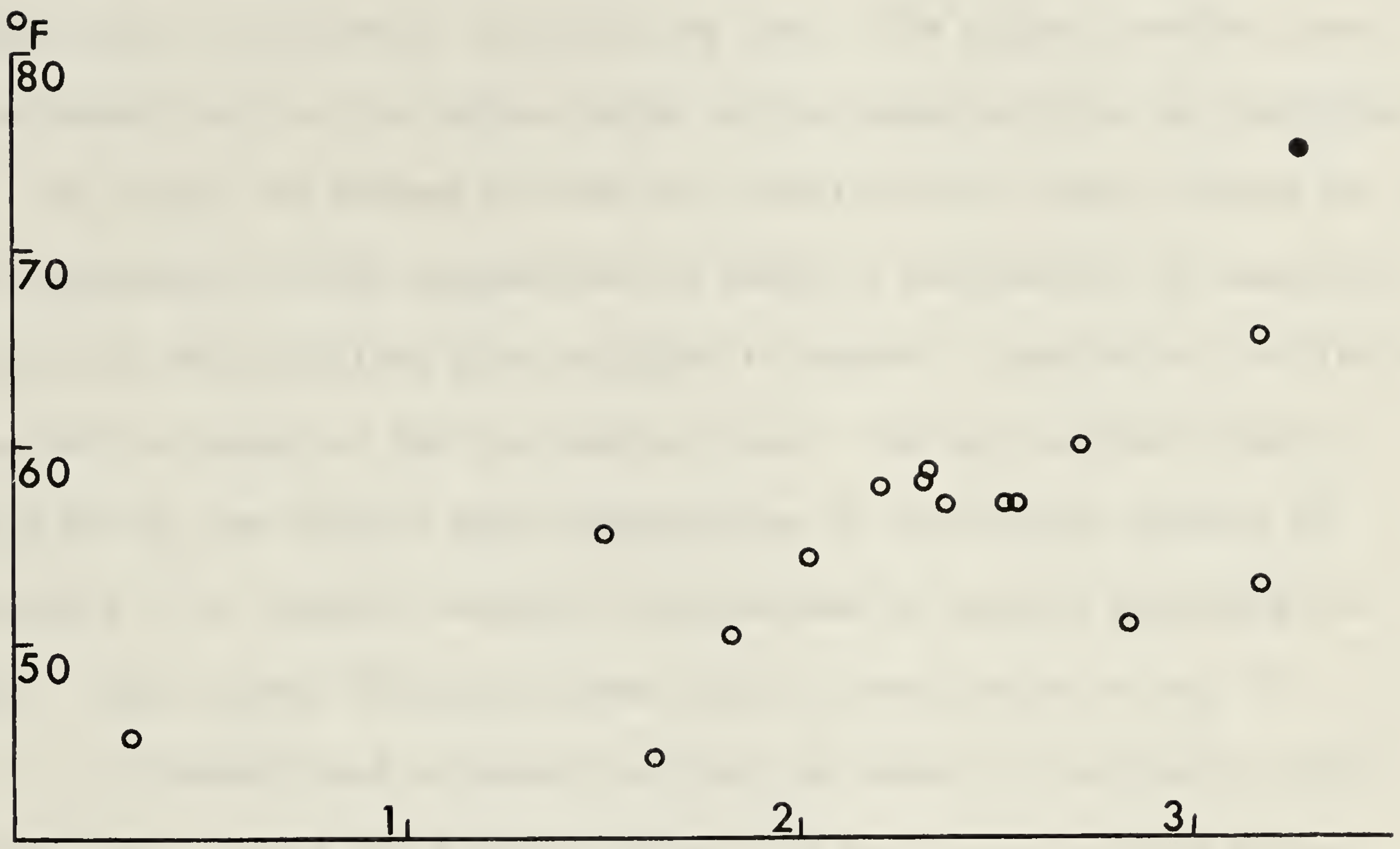


Figure 5 - Values of mean temperature plotted against the $\frac{\sum \log(n+1)}{N}$ values of the number of Trichoptera taken per 1 hr. period, in an ultra-violet light trap at Ile Ste. Hélène, Montreal, during the summer of 1964. Means obtained only from the data of those periods between sunset and sunrise. The means of each night are plotted separately. Ordinate in °F ; abscissa in logs.

The black dot represents the night of 18-19/vii, for reasons given in the text.

That is, on an evening of high temperatures (70-80^{o}F), one can expect a large catch, the opposite also holding true. The nightly catches taken as a separate part of the project offer better opportunities to demonstrate this. No values are worked out for the correlation of total catches per night and temperature, as this examination is simply a preliminary to examining the data for those periods when sunlight is absent. Correlation coefficient values will be provided for the factors then. One way in which nightly catches may be low despite high temperatures is by relative absence of Trichoptera (i.e. natural seasonal fluctuations of species composing the catch). This serves to explain some lack of correlation in Fig. 5.

Although wind strength has thus far shown no correlation with $\frac{\Sigma \log (n+1)}{N}$ (taken for a single night), it may, under certain circumstances, influence flight activity. The best available example is the data for the night of 18-19/vii, which is set out in the following table:

Catch	1	2	3	4	5	6	7	8	9
log (n+1)	1.60	2.57	2.73	2.71	3.15	4.20	4.15	4.40	3.91
T^{o}F	89	88	87	86	85	85	84	83	83
Wind (mph)	24	25	25	23	14	8	5	3	1

Temperature was high and decreasing slowly and steadily. But only a morning peak is discernable. The evening peak seems to be quite absent. Actually it exists, not as a peak *per se*, but as the small stubs formed by the log (n+1) values of periods 2 and 3.

If the wind had maintained a high speed throughout the night of 18-19/vii, Fig. 3-i would almost certainly have been much

like Figs. 3-c, h or p. But the wind suddenly dropped and, as seen above, a 'simultaneous' upsurge occurred in numbers of Trichoptera taken. If there had been only moderate wind throughout that night, the evening peak would presumably have occurred, giving larger catches than the 25,000 per hour of the morning catches, which is just about capacity for the trap, and thus probably swamping the LaFrance trap. Instead of which the catch taken on this night is now one of the most useful of all catches taken during the summer. It will be noted in Fig. 5 that the plotted position of 18-19/viii (marked •) is one of the poorly correlated catches. If the evening had been 'normal', wind being absent, the point would probably have been located well to the right, in line with the others.

Wind on the night of 16-17/vi varied from 17 to 22 m.p.h. and the pattern is clear (Fig. 3-b). It varied from 13 to 18 m.p.h. on 23-24/vii and the pattern appeared (Fig. 3-j). On 1-2/viii the wind varied from 2 to 8 m.p.h., but the temperature fell 14°F. The pattern is obscured by fluctuations between the peak (Fig. 3-k).

Thus, if the effect of wind be removed, it is seen that temperature plays a major role in determining 'height' of the graphed pattern from the abscissa, 'height' of the pattern being indicative of the effect of temperature on activity. It is assumed that the large numbers flying at higher temperatures is not indicative of any attempt to avoid areas of high temperature, but is a case of the Trichoptera being less 'concerned' with heat loss at higher temperatures, and thus more willing to expend energy in flight. The fact that most Trichoptera species fly

en masse at night and not during the day, when it is even warmer, suggests an inhibiting effect of either or both of temperature or light. (See Andrewartha & Birch, 1954, section 6.22, for a discussion of temperature effects on animal activity.) Wind can only make it difficult, or impossible, for the insects to fly, and thus to come to the trap, no matter how much they may be encouraged to fly by high temperature. The pattern, remaining unchanged, will only be decreased in magnitude. If the wind is fairly constant throughout, the pattern will probably retain its integrity. If temperature should suddenly drop, an abrupt drop in numbers taken could occur. If wind drops abruptly and far, from a high value, an increase in numbers taken can be expected, and vice versa. Thus wind and temperature are seen to be major factors in determining the overall catch for any one night. But the peaks, barring such exceptional circumstances as occurred on the night of 18-19 July, will be detectable. The peak values will stand well above those of adjacent periods, regardless of prevailing conditions, except natural light (see Andrewartha & Birch, 1954, section 8.4 for a full account of the role of light values as a trigger to periodic activity).

To determine more precisely the effects of environmental factors the peak period data must be omitted from consideration, and the inter-peak periods examined more closely; this is done in the following section.

THE PERIODS BETWEEN THE PEAK PERIODS - The periods involved here are numbers 3 to 7, 3 to 8, or 3 to 9, depending on sunrise shift.

The meteorological data used here are given in appendix B.

Figs. 6 to 8 illustrate $\frac{\Sigma \log (n+1)}{N}$ plotted against mean temperature, mean wind, and mean saturation deficit respectively, for the appropriate set of periods in any given night. Fig. 6 shows a strong correlation of mean temperature with $\frac{\Sigma \log (n+1)}{N}$. Mean wind speed and mean saturation deficit show little apparent correlation. Saturation deficit is now abandoned from further consideration as it oscillates frequently and occasionally with violence, in a short time. Wind, for previously demonstrated reasons, is retained, despite apparent lack of correlation. In fact it is because wind is secondary to temperature that it appears uncorrelated. Fig. 7 indicates that any correlation present is negative, as would be expected. Figs. 6, 7 and 9 may be used to demonstrate the role of wind in disrupting the effect of temperature on the flying population and thus disrupting the correlation between $\frac{\Sigma \log (n+1)}{N}$ and mean temperature for any one night. Fig. 7 presents $\frac{\Sigma \log (n+1)}{N}$ plotted against mean wind speed. Note the distribution of catch nights relative to each other. Fig. 9 gives $\frac{\Sigma \log (n+1)}{N}$ plotted against mean temperature times mean wind speed. It will be seen that the relative distribution of each night is unchanged. As temperature is also involved the vertical distribution in Fig. 9 is slightly greater. In Fig. 6, showing $\frac{\Sigma \log (n+1)}{N}$ plotted against mean temperature, the relative distribution is entirely different, and the correlation is much improved. This seems to be fairly convincing evidence of the overriding effect of temperature, and the subsidiary, disrupting, effect of wind, on flight

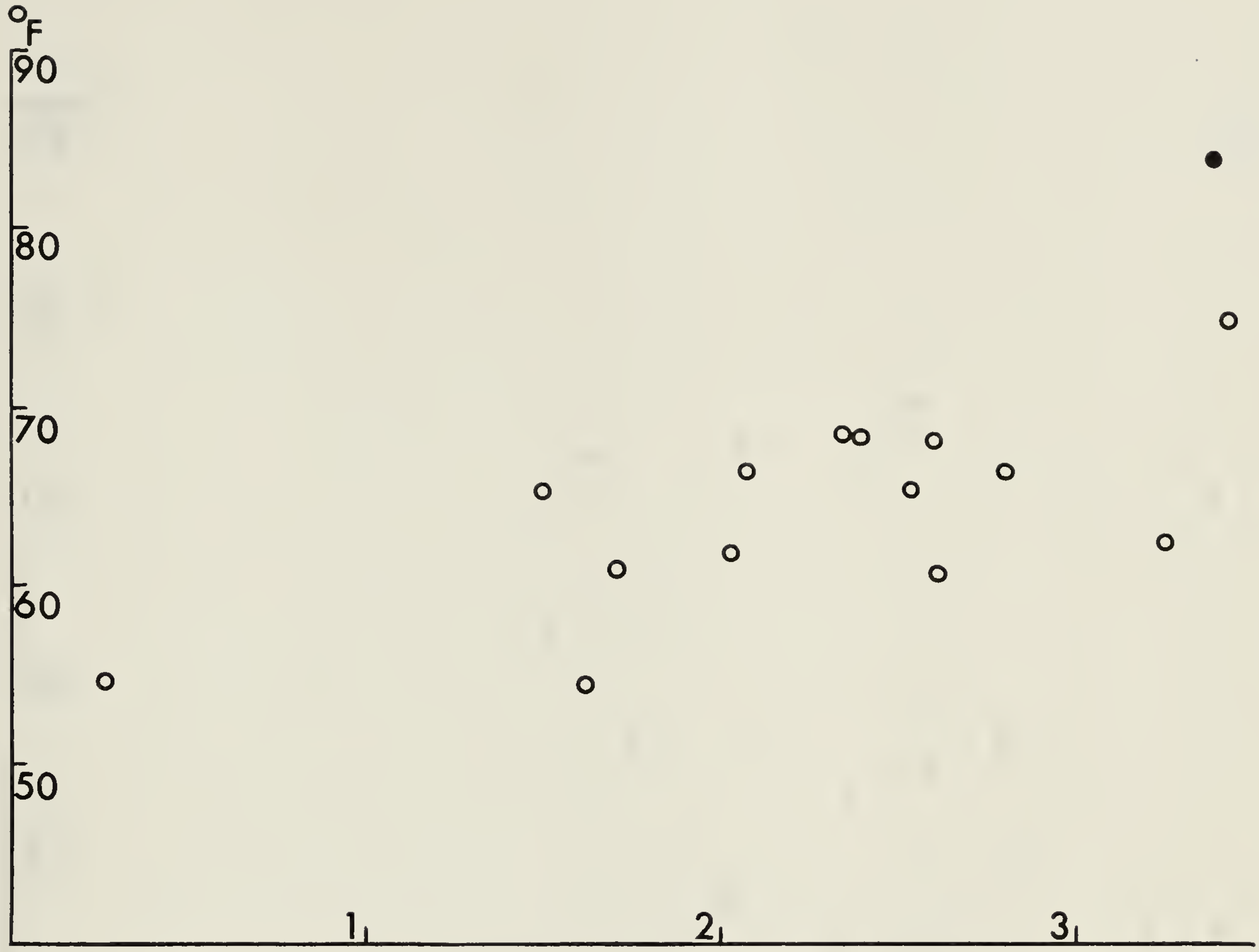


Figure 6 - Values of mean temperature plotted against the $\frac{\sum \log(n+1)}{N}$ values of the number of Trichoptera taken per 1 hr. period, in an ultra-violet light trap at Ile Ste. Hélène, Montreal, Summer 1964. Means obtained only from the data of those periods between the evening and morning peaks, which are essentially coincident with sunset and sunrise. The means of each night are plotted separately. Ordinate in °F ; abscissa in logs. The black dot represents the night of 18-19/vii, for reasons given in the text.

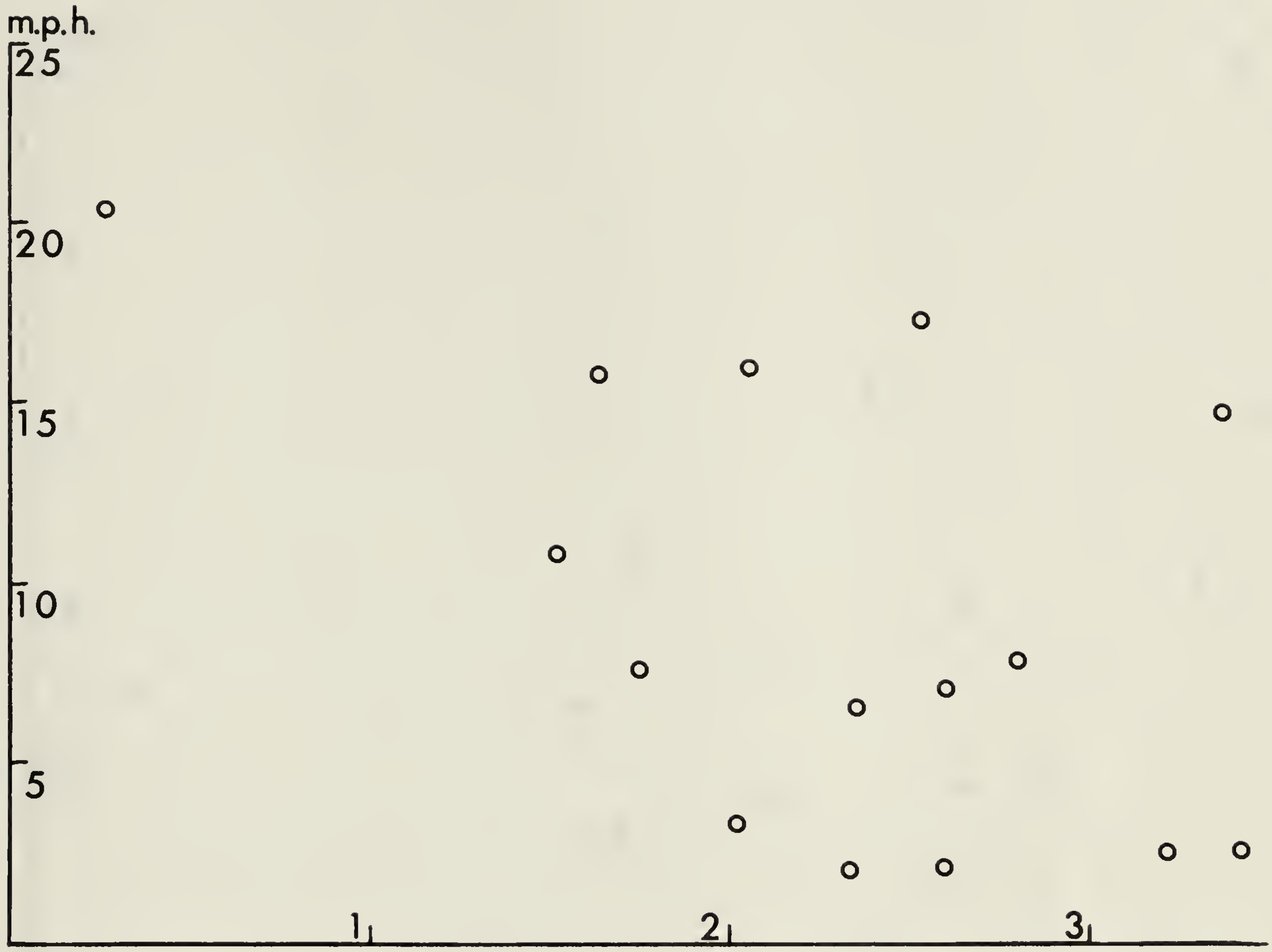


Figure 7 - Values of mean wind speed plotted against total numbers (converted to $\frac{\sum \log(n+1)}{N}$) of Trichoptera taken at an ultra-violet light trap at Ile Ste. Hélène, Montreal, summer 1964. The values were derived from the data of those periods between the peaks. The means of each night are plotted separately. Ordinate in m.p.h. (wind) ; abscissa in logs.

Figure 8 - Values of mean saturation deficit plotted against total numbers (converted to $\frac{\sum \log(n+1)}{N}$) of Trichoptera taken at an ultra-violet light trap at Ile Ste. Hélène, Montreal, summer 1964. The values are derived from the data of those periods between the peaks. The means of each night are plotted separately. Ordinate in inches of mercury ; abscissa in logs.

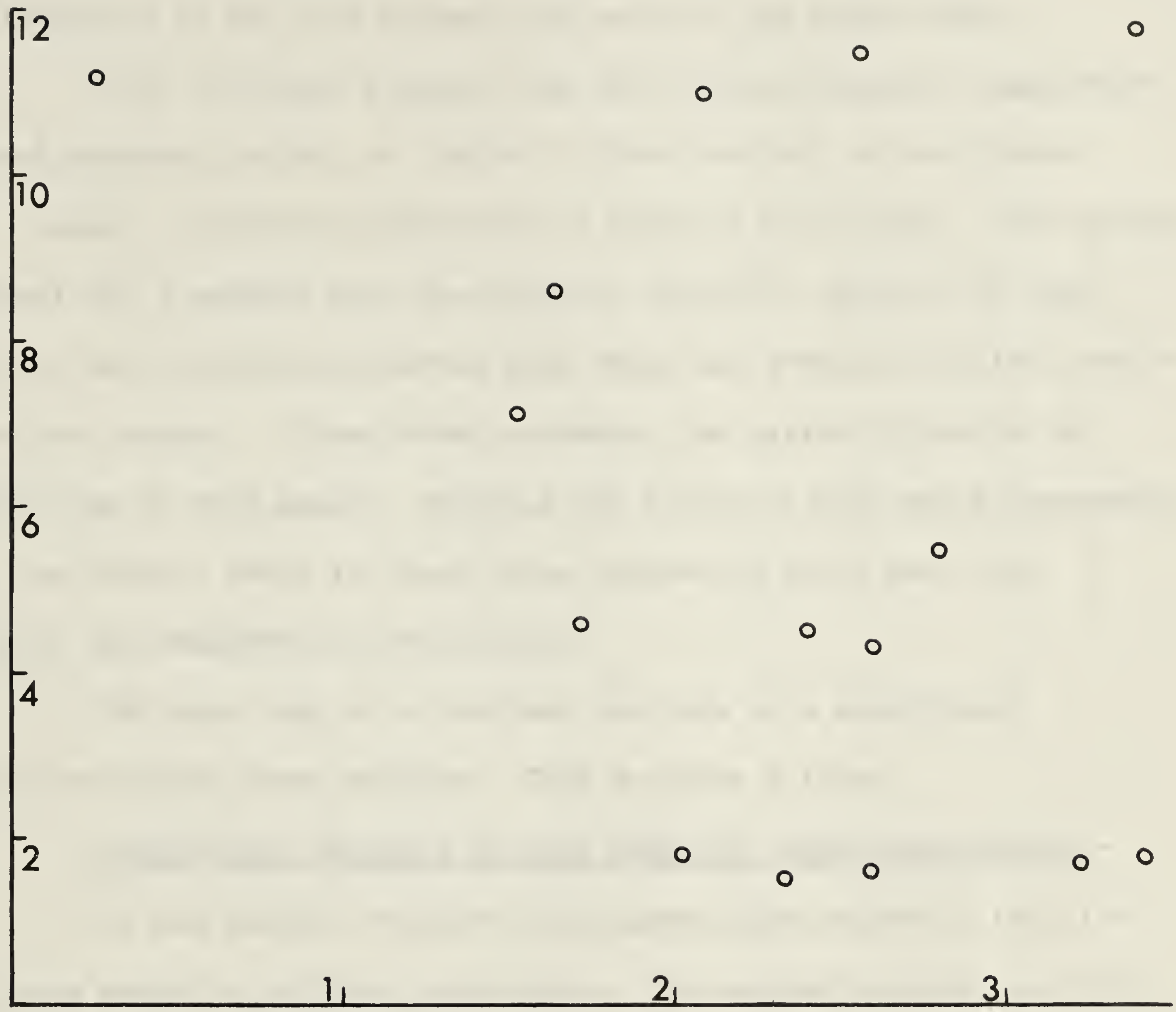


Figure 9 - Values of mean temperature times mean wind speed plotted against total numbers (as $\frac{\sum \log(n+1)}{N}$) of Trichoptera taken at an ultra-violet light trap at Ile Ste. Hélène, Montreal, summer 1964. The means are obtained from the data of those periods between the peaks; the means of each night are plotted separately. Ordinate in hundreds ($T^{o}F \times$ wind in m.p.h.); abscissa in logs.

in Trichoptera in the time between the peaks of any given night.

Fig. 10 simply presents log (n+1) plotted against temperature for each separate period, as limited in this section, in each catch night. Again a definite correlation is seen, in more detail. The crosses represent the 5 catches from the night of 18-19/vii (point • in Figs. 5 and 6), and it will be observed that three are anomalous to the remainder of the scatter. These three represent the periods prior to the drastic drop in wind speed. Removing the effect of wind would presumably cause the numbers taken in these three periods to shift back into line with the remainder of the scatter

The next step is to subject the data to a statistical analysis to verify these results. This analysis follows.

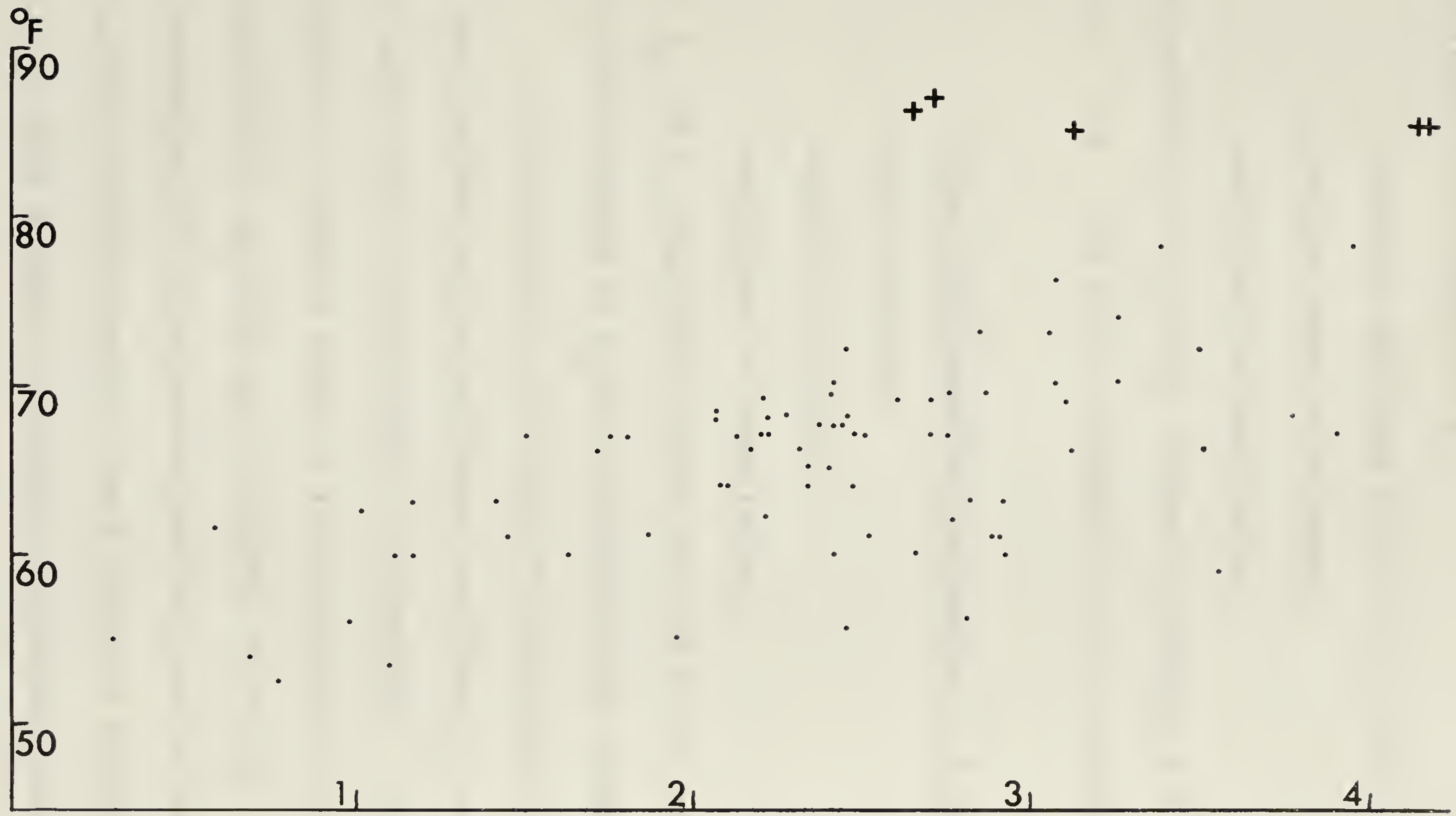
STATISTICAL ANALYSIS OF DATA FROM THE INTER-PEAK PERIODS -

It was decided that the most appropriate method in the circumstances would be multiple correlation. The method employed is that set out in detail by Croxton and Cowden (1955), chapter 21.

Values of log (n+1) are designated in the following as X_1; of temperature, X_2; of wind speed, X_3. Details of the calculations are omitted, suffice it to summarize the results, X_1 being the dependant variable:

Using one independent variable: X_2 or X_3

Total variation of X_1,	$\Sigma\ x_1^2 = 69.7634$
Variation explained by use of X_2 only	$= 32.4282$
Standard error of estimate	$= 0.6789$
Coefficient of correlation,	$r_{12} = +0.6817$



<u>Figure 10</u> - Values of temperature plotted against total numbers (as log(n+1)) of Trichoptera taken at an ultra-violet light trap at Ile Ste. Hélène, Montreal, summer 1964. Each inter-peak period plotted separately. Positions marked by crosses are for the night of 18-19/vii, for reasons given in the text. Ordinate in °F ; abscissa in logs.

Thus variation in X_2, or temperature, serves to explain 68% of the variation of X_1, or log (n+1); i.e. 68% of the changes in X_1 are associated with changes in X_2.

Variation explained by use of X_3 only		= 14.3372
Standard error of estimate		= 0.8272
Coefficient of correlation	r_{13}	= -0.4533

Thus variation in X_3, wind, serves to explain 45% of the variation of X_1; i.e. 45% of the changes in X_1 are associated with changes in X_3.

<u>Using two independent variables: X_2 and X_3</u>

Total variation,	Σx_1^2	= 69.7634
Explained variation,	$\Sigma x_{c.23}^2$	= 39.6811
Coefficient of correlation,	$R_{1.23}$	= +0.7541

Thus X_2 and X_3 together, account for 75% of the variation of X_1; i.e. 75% of the changes in X_1 are associated with changes in X_2 and/or X_3.

Thus most of the blame for variation in log (n+1) between the peak periods may be attributed to, firstly, temperature and, secondly, wind speed which, as predicted, is secondary. As their combined effect on numbers of insects taken is to the extent of 75%, the interaction of temperature and wind may be assumed to be 38% (i.e. 45-(75-68)=38). The remaining 25% of variation does not seem to warrant any attempt to include relative humidity and saturation deficit. There is almost certainly some amount of intrinsic variation involved on the part of the Trichoptera themselves. Also, error may be involved in trapping, reducing the 25% unexplained variation still further. The labour involved

in including a third and fourth independant variable, as opposed to only two, to explain less than 25% of the variation, would seem ill spent.

To test the reliability of $R_{1.23}$, the 'F' test, as in Croxton and Cowden (1955) is used. That is, $R_{1.23}$ is being tested to determine whether it significantly exceeds zero, (i.e. is the correlation good?). Thus:

$$F = \frac{R^2_{1.23} \;/\; (m-1)}{(1-R^2_{1.23}) \;/\; (N-m)}$$

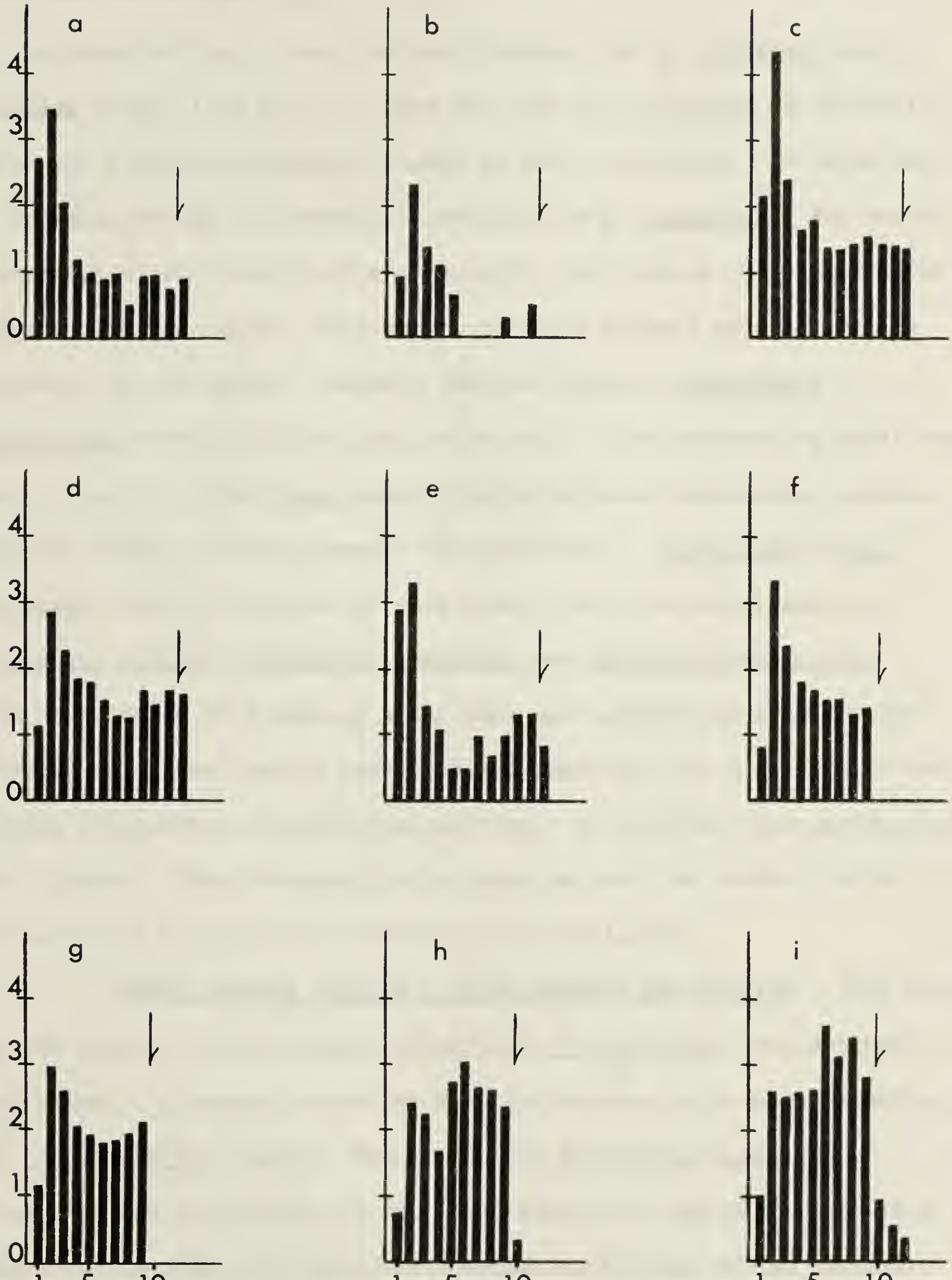
where m is the number of column means and N is the number of observations.

$$F = 51.7$$

Consulting appendix M in Croxton and Cowden reveals that the minimum acceptable value of F occurs between 7.76 and 7.32, at a confidence limit of 0.001. Here F is far greater than the minimum, indicating, according to Croxton and Cowden, that $R^2_{1.23}$ is 'clearly significant'. In other words, the correlation between X_1 and $X_{2\ \&\ 3}$ appear to be very good.

THE PATTERN AT THE SPECIES LEVEL - The graphed pattern of only one night is used for each species as the species patterns follow the total numbers pattern closely. The night chosen for each species was that which showed the pattern best. Varying seasonal occurrence prevented the same night being used for all species, but only two nights were needed: 13-14/vi and 25-26/viii. Species and night are given in Fig. 11-a....g. It will be seen in these graphs that all seven species tend to follow the pattern, with differences, of course, but

Figure 11 - Graphs showing the 'ideal' pattern of arrival, throughout selected nights, of the numbers (as log(n + 1)) of selected species of Trichoptera at an ultra-violet light trap at Ile Ste. Hélène, Montreal, summer 1964. Two extra graphs, Figs. 11-h and i, are included for reasons given in the text. Ordinates in logs ; abscissae in 1 hr. periods, log(n + 1) values plotted at the period mid-points. Sunrise indicated by the arrows. Sunset coincident with the first period mid-point. The species and nights involved are as follows : a) *Hydroptila spatulata*, 25-26/viii ; b) *Cheumatopsyche speciosa* 25-26/viii ; c) *Protoptila maculata*, 25-26/viii ; d) *Hydropsyche recurvata*, 25-26/viii ; e) *Psychomyia flavida*, 25-26/viii ; f) *Athripsodes cancellatus*, 13-14/vii ; g) *Athripsodes tarsipunctatus*, 13-14/vii ; h) *Hydropsyche recurvata*, 18-19/vii ; i) *Cheumatopsyche speciosa*, 18-19/vii .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minor and inconsequential.

Included in Fig. 11 are two extra graphs, for H. recurvata and C. speciosa (Figs. 11-h and i). They are both for the night of 18-19/vi in which the high wind suddenly dropped to very low values. In these two figures an evening peak is discernable, especially in H. recurvata. The overall depression of the first half of the night still exists, but the species numbers rose to a peak, fell away, the wind dropped and the species recovered to the assumed 'normal' for that night. Athripsodes cancellatus shows this also, but not so well. The interesting point here is, that it was the three large species which produced discernable evening peaks of flight activity despite the high wind. Athripsodes tarsi-punctatus shows no evidence of this peak. The three other species: Psychomyia flavida, Protoptila maculata, and Hydroptila spatulata, show no evidence of a peak at all: they are referred to as the micro-Trichoptera. Thus size is seen to be of importance to a species in maintaining the pattern of nighttime activity, if high and fluctuating winds are a factor. This diversity due to size may well be another factor in the 25% variation in log (n+1) remaining to be explained.

SUMMER AVERAGE PATTERN - TOTAL NUMBERS AND SPECIES - Figs.4-aa'.... hh' are graphs of the patterns using both $\frac{\Sigma \log (n+1)}{N}$ and arithmetic mean values. Allowance should be made for sunrise shift when examining the $\frac{\Sigma \log (n+1)}{N}$ graphs. The graphs for Hydroptila spatulata (Figs. 4-a and a') provide an excellent example of the effect of using logarithms to damp the effects of abnormal conditions on the intrinsic pattern, in this case the winds of the night of 18-19/vii.

<u>TEN MINUTE CATCHES - TOTAL NUMBERS</u> - Figs. 12-a....j show patterns for individual nights using log (n+1) values, and Figs. 13-aa' show the average pattern for the summer using $\frac{\Sigma \log (n+1)}{N}$ and the arithmetic mean respectively. The broken lines represent those values obtained by using catches beyond the minimum of 13, when means had to be derived from the data of fewer nights. Total numbers (n) per catch will be found in appendix C.

Examination of the mean values of total numbers per 10 min. period, and of the species separately, for the summer (Figs. 13-aa' ....h) shows that the use of $\frac{\Sigma \log (n+1)}{N}$ does not give as clear a representation of what happens as does use of the arithmetic mean. Examination of the graph of arithmetic means shows the first 5 catches to be minuscule. The sixth is noticeably larger, and in the seventh and/or eighth an almost meteoric upsurge occurs, followed by a much slower, though speedy,falling off till a much lower level is reached. This is followed by fairly steady or gently fluctuating catch numbers at that level, with a tendency to drop off to still lower levels very slowly.

Use of $\frac{\Sigma \log (n+1)}{N}$ tends to smooth out the peak. The initial upsurge persists, though in more subdued form, as the initial 5 or 6 catches are accentuated somewhat. Civil twilight is indicated half way between plotted positions of catches 6 and 7, at the catch mid-points. So if a specific light intensity plays a part in 'triggering' the evening peak, it seems to occur just prior to civil twilight, in period 6.

This is all that can profitably be said regarding the fine

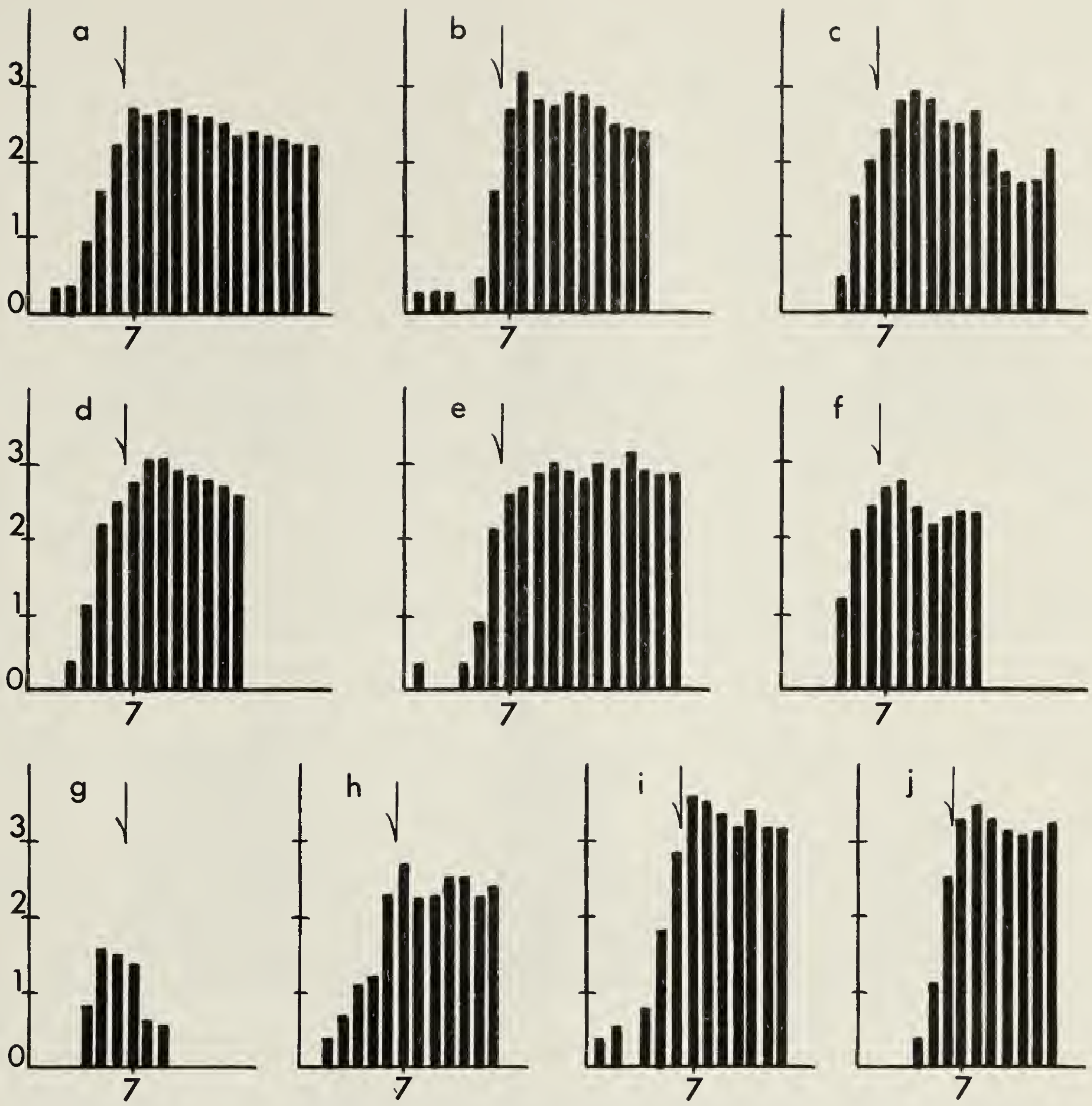
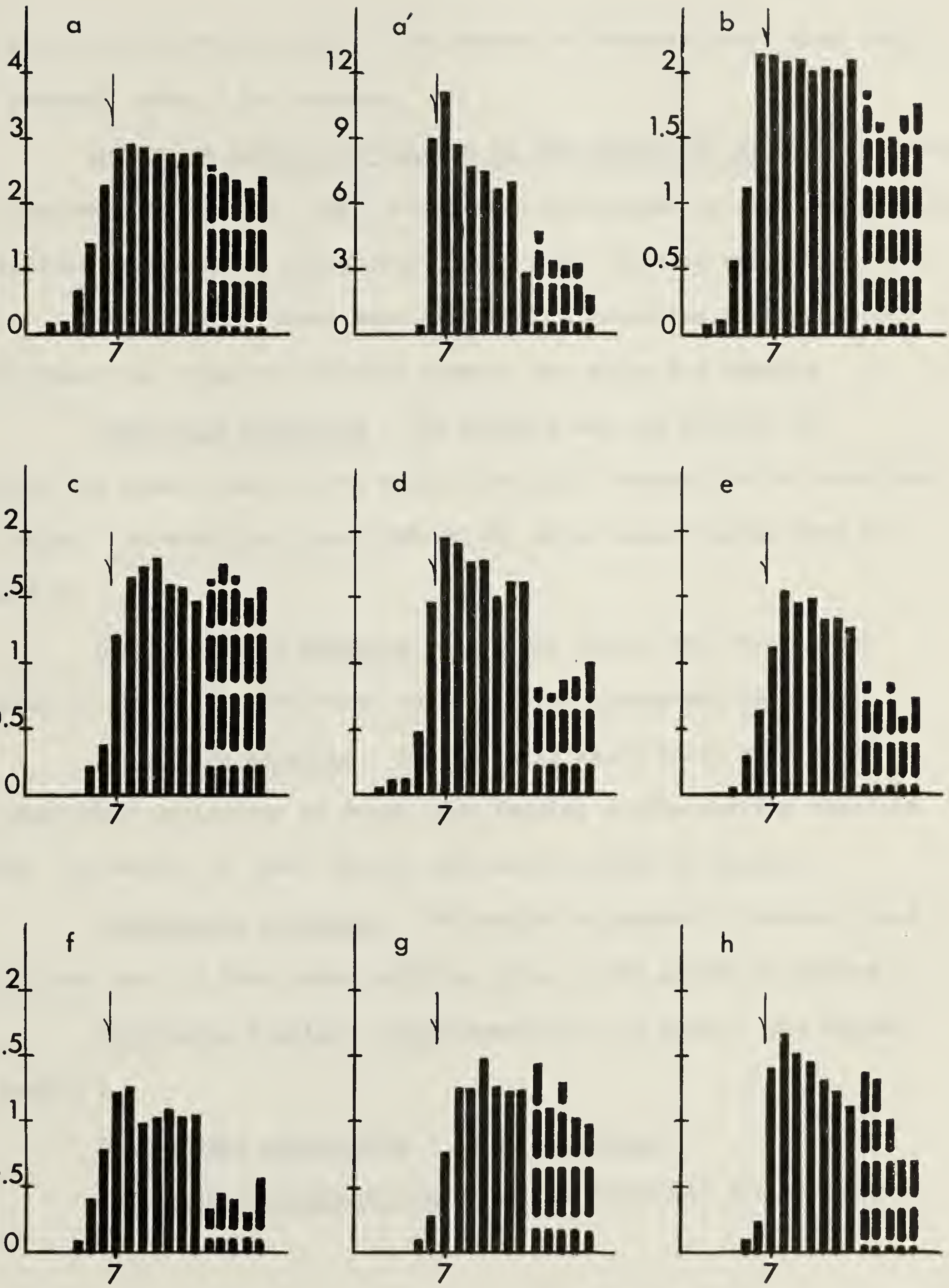


Figure 12 - Graphs of total numbers (as log(n + 1)) of Trichoptera taken at an ultra-violet light trap at Ile Ste. Hélène, Montreal, summer 1964, for each night on which 10 min. catch periods were used. Ordinates in logs ; abscissae in 10 minute periods, log (n + 1) values plotted at the period mid-points. Civil twilight indicated by the arrows. The nights involved are as follows : a) 2-3/vii ; b) 7-8/vii ; c) 14-15/vii ; d) 19-20/vii ; e) 24-25/vii ; f) 6-7/viii ; g) 13-14/viii ; h) 23-24/viii ; i) 26-27/viii ; j) 30-31/viii .

Figure 13 - Mean numbers (as the arithmetic mean, or $\frac{\Sigma \log(n+1)}{N}$) of Trichoptera taken per 10 min. period at an ultra-violet light trap at Ile Ste. Hélène, Montreal, for those equivalent periods of each night on which trapping was carried out, summer 1964. Ordinates in logs, except in Fig. 13-a' where it is in hundreds ; abscissae in 10 min. periods, with values plotted at the period mid-points. The arrows mark civil twilight. The broken lines represent those means derived from less than the normal number of values, as trapping generally, but not always, continued beyond the basic 13 periods. Species involved are as follows : a-a') Total numbers ; b) *Hydroptila spatulata* ; c) *Cheumatopsyche speciosa* ; d) *Protoptila maculata* ; e) *Hydropsyche recurvata* ; f) *Psychomyia flavida* ; g) *Athripsodes cancellatus* ; h) *Athripsodes tarsipunctatus* .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0
7

structure of the evening peak. The effects of factors other than light are examined under 1 hr. catches.

RATIOS OF SEXES, AND GRAVIDS TO NON-GRAVIDS AT NIGHT - As mentioned in 'Treatment of catches' the species were determined to sex, and the females determined as gravid or non-gravid. Only 1 hr. catches are used.

SEX RATIOS - These were examined to determine if there might be differential times of activity between the males and females.

Hydroptila spatulata - The females may lag behind, or precede the males, but, on the whole, the ratio varies little throughout the night. Generally at least 50% of the total catch has arrived by period 3.

Cheumatopsyche speciosa - At least 50% of the total catch arrived by period 3. The ratio varies little throughout the night.

Protoptila maculata - The ratio is essentially unvarying, but when wide deviations do occur, the females arrive earlier than the males. As above, at least 50% of the catch arrives by period 3.

Hydropsyche recurvata - The ratio is generally constant, and variations tend to have males arriving first. 50% arrive by period 3.

Psychomyia flavida - Parthenogenetic; no males. 50% arrive by period 3.

Athripsodes cancellatus - As *H. recurvata*.

Athripsodes tarsipunctatus - Rather difficult due to small

numbers. Deviations of females seem to occur either way. 50% usually arrive by period 3.

RATIO OF GRAVIDS TO NON-GRAVIDS

Hydroptila spatulata - Generally a constant ratio, with variations of non-gravids either way.

Cheumatopsyche speciosa - Generally close adherance to the ratio, and deviations of non-gravids seem to occur to result in earlier arrival.

Protoptila maculata - Ratio adhered to. Non-gravids may vary either way.

Hydropsyche recurvata - As above.

Psychomyia flavida - Generally close adherance, with major deviations of non-gravids to arrive later.

Athripsodes cancellatus - Ratio usually fairly constant.

Athripsodes tarsipunctatus - As above, but too few individuals to say which way deviations trend.

On the whole, therefore, it seems safe to conclude that the pattern of total numbers of Trichoptera taken at light is not due to any one sex or female condition, of any one, or more species.

DISCUSSION

PREVIOUS STUDIES OF NOCTURNAL PATTERNS OF ACTIVITY IN TRICHOPTERA - Light trap studies of the nocturnal flight activity rhythms of insects are legion. Such are those by Williams (1935 and others), Stage and Chamberlin (1945), Lewis and Taylor (1965), Southwood (1960), Corbet and Tjønneland (1955), and Brindle (1957a, and b, and 1958), to mention only those few which I have found to be of immediate interest. Most papers deal with almost anything else but Trichoptera, and if they do, it is mostly just in passing. This is not surprising, as they are generally of little importance as adults or, if taken, are paid scant attention. There are studies on Trichoptera on a day-to-day basis throughout the seasons (Crichton, 1960; Marshal, 1939), rather than on an hour-by-hour basis as here, and consequently they are of little interest in the present context. Unfortunately, no studies appear to have used nonattractive methods of trapping specifically for Trichoptera.

Before going on to the natural affinities of the pattern at light, the conclusions of previous workers on factors influencing the pattern, will be examined.

THE PATTERN AT MONTREAL - The pattern found in the present study has the following characteristics: bimodal; the evening peak relatively much more pronounced than the poorly developed morning peak; the pattern of numbers in periods exclusive of the peak periods forms a gradually decreasing slope from the evening peak till the slight rise to the morning peak; the interpeak slope may be punctuated by

fluctuations of varying degrees of violence, dependant on meteorological factors; the evening peak is preceeded by a swift upsurge from zero; the morning peak is terminated by an abrupt drop-off in numbers to zero, or almost zero. Referring to Corbet and Tjønneland's (1955) classification of relative development of the two peaks in East African Trichoptera, the present 7 species seem to fit class 2 well; "Both peaks discernable, dusk peak far more pronounced".

METEOROLOGICAL FACTORS AND THE PATTERN - The day-to-day effects of temperature and wind were dealt with here only superficially, for two reasons: 1). The paucity of data did not warrant any attempted emulation of, for example, Williams' work on Lepidoptera (1961) and Simuliidae (1962) in this respect and, 2). this was not the purpose of the study. The analysis here was done simply as a step towards examination of the inter-peak fluctuations, and to aid in determining the role of light. The gross effect of temperature and wind on potential magnitude of the total catch on any one night has been demonstrated and Williams (1961) says that "The activity of insects on any one night is very largely determined by temperature and wind,...". Brindle (1957a) mentions the effect of wind on two night's catches. Each night the wind arrived from a different quarter: once from a river, once from a reservoir. The species composition differed remarkably on these nights and corresponded with the fauna of the river, or reservoir, depending on wind direction. One species was common to both nights however, but not to both habitats, "...a strong flyer" as Brindle says and, being a

species of Phryganea, it is a 'large' trichopteran. This, again, agrees with the evidence of the preceeding results to the same effect, from the night of 18-19/vii, for the differential effect of wind depending on insect size. Brindle also examines the possible effect of temperature and relative humidity and finds higher temperatures, associated with lower relative humidity, better for larger catches. It is uncertain how he regards relative humidity, but certainly there is agreement on temperature effects. As stated in the section on sources of error the nights on which trapping was avoided due to the likelihood of swamping catches, were hot and humid.

Thus, in the light of the few papers which deal specifically with Trichoptera activity patterns and weather, and of Williams' (1961) statement, the present determination of temperature and wind as prime factors in determining the total catch of any one night, or the height of the graphed pattern of numbers from the abscissa, seems reasonably well justified.

THE ROLE OF LIGHT VALUES - The role of light in producing the peak in numbers taken at dusk and dawn, at artificial light, has previously been examined only by Corbet and Tjønneland (1955). They concluded that flight is inhibited by light at greater than a certain intensity. At or below the critical intensity is a light intensity conducive to mass flight activity. Below this value flight activity dwindles but does not cease entirely. They speculate that activity is positively correlated with light intensity, up to the inhibiting value, but do not explain why flight occurs when no natural light

(sunlight) occurs, as between the peak periods.

It has been shown here that the evening peak was preceeded by a sharp upsurge from zero, just prior to civil twilight. The sharp drop-off in the morning peak would seem to mirror the sharp rise in the evening peak. It is suggested that, on detailed examination of the morning peak, the sudden drop will be found to occur very close to, but after morning civil twilight. One possible explanation for the relative insignificance of the morning peak may be found in the fact that light is increasing, rather than decreasing. It is suggested below that the evening peak is triggered by a certain light value, but that all that is needed for night activity as such, is darkness, or at least light lower than a certain intensity. This being so, the increase in light in the morning, prior to attainment of the crucial light intensity, should have little effect on the catches taken. Then, when the critical intensity occurs, little time will be available for a peak to occur and attain any great size, as the conditions, of full daylight which lie beyond, are inhibiting to flight.

Corbet and Tjønneland (1955) suggest that some credence may be placed in this drop-off being merely an artifact of the light trap source being blanketed by natural light. But they go on to suggest that, even if this were so, the drop-off would hardly be as abrupt. Then again, there _is_ that small peak immediately prior to the sharp drop-off, suggesting a definite reaction to light. With 1 hr. catches used here this is rather a dangerous assumption however, without guides from other work. Corbet and Tjønneland used 10 min.

catches throughout the night.

It seems reasonable to suppose that, if the particular light intensity, or range of intensities, concerned in production of the peaks, could be omitted, the pattern would seem to be a truncated normal type curve; or possibly a curve skewed to the left. That is, it is possible that a certain light value incites the insects to unusual heights of activity, hence the peaks, but values below this, down to zero, would incite them to activity at a lower level, dependent on other environmental factors only, light being of use only by its absence. The 'peak' of the skewed pattern being initial no-light activity, followed by the previously mentioned declining curve of exhaustion.

Corbet and Tjønneland (1955) regard it as unsatisfactory to use decreasing light <u>only</u> as a <u>release</u> from daytime flight inhibition, due to the presence of two peaks in at least some of their species, as in all of those examined here. With a second peak prior to dawn, they argue that low light intensity must, instead, provide a stimulation to flight activity. Referring to Stage and Chamberlin (1945) they point out that the same bimodal pattern is demonstrable at night independent of any response of the insects to the trap (mosquitoes in this case). Inasmuch as the peaks cannot be artifacts of the light trapping, by virtue of the decline after the evening peak when all sunlight is absent, and tests run to determine if the peak might be an initial upsurge due to the sudden switching on of the trap light, it will have to be assumed that such activity occurs naturally, and in response to natural light. This is essentially their argument

which is agreed with here. Discarding release of flight inhibitions by means of low light intensity, as a reason for the evening peak, and substituting stimulation by low light instead, is not agreed with.

Stimulation seems to be a reasonable answer for the morning peak: the night is over, sunlight appears and the Trichoptera are 'stimulated' to greater activity, until a high light value inhibits further flight. While the morning peak may thus be due to light stimulation, this cannot be the case in the evenings, when light is decreasing. It is more likely that the evening peak results from release from an inhibition by light above a certain intensity. Thus the evening peak may be taken as the result of a release, permitting the Trichoptera to mate and oviposit, presumably much safer from predators than in full sunlight. Unlike mosquitoes they may feed best in the daytime, if at all, while resting on plants, with plant fluids or rain water immediately available. It is doubtful if the peaks can be interpreted as migrations to and from daily resting places: Trichoptera may rest almost anywhere, and the difference in peak size does not support the idea.

Thus it is concluded that the evening peak results from release from inhibiting light intensities, and the morning peak from stimulation by low, but increasing, light.

METEOROLOGICAL FACTORS AND THE INTER-PEAK PERIODS - It has already been determined here that the inter-peak periods produce a pattern of steadily but gradually decreasing numbers from evening to morning peaks. This appears to be the intrinsic pattern, and is supported

by the work of Corbet and Tjønneland (1955). Meteorological factors play a vital role in determining the elevation of the pattern provided their action is steady or non-violent throughout the night. However, if these factors fluctuate more violently than usual, or at least change suddenly, the inter-peak pattern will reflect these sudden changes by fluctuating erratically, or changing suddenly itself.

Williams (1961) mentions the rapid changes possible in the pattern of activity, as revealed by numbers, in a very short time "...sometimes a matter of only hours or minutes". But as he is concerned there with seasonal patterns, he goes no further. He cautions on the distinction to be observed, in regarding a single night's catch, between activity and population level (or, how many insects are there available to catch?). No matter how ideal the night, if the population is not there, the catch will be poor, but the activity pattern will show up anyway. This is one reason which is advanced here for the lack of precise correlation between temperature and numbers (as log (n+1)). Brindle 1957a) essentially supports this view in drawing a parallel between the Lepidopterist's 'good' night and that of the Trichopterist.

Corbet and Tjønneland ran their trap on nights in which the meteorological factors varied or changes little from night to night, or within nights. Thus they had no opportunity to determine the effect of fluctuations on their catches. They used 10 min. catches throughout the night and those of their species which showed patterns similar to the one here, but much more clearly, showed a

certain amount of fluctuation between the peaks which is not directly attributable to any factors considered here, and can probably be labelled intrinsic. But though they experienced only light breezes they did demonstrate the differential effect of wind on species of various sizes, as has been done here using the night of 18-19/vii; they did not relate wind directly with pattern fluctuations, but appear to have done so indirectly. Thus part of the intrinsic variation may be due to light wind and small species.

NATURAL AFFINITIES OF THE PATTERN - The only certain way to determine the actual nocturnal, or diurnal, flight activity pattern of Trichoptera is by some trapping method, such as the rotary nets used by Stage and Chamberlin (1945) for Alaskan mosquitoes, which may collect the insects independently of any response on their part.

It seems reasonable to suppose that, in bimodal species such as were worked with here, the pattern between the tips of the peaks is a reflection of the natural pattern. The gradual decrease from the usually much larger evening peak, towards the morning peak is ignored for the present. The point is that a certain basic level of activity appears to be demonstrated between the peaks. Whether this is the same level as the daytime flight activity level, or higher or lower, cannot be said. But daytime flight is not uncommon in Trichoptera (Brindle, 1957a; Peterson, 1952; Lewis and Taylor, 1965). Daylight flight in several species, especially in late afternoon, was frequently noted at Ile Ste. Hélène, and swarming activity, especially by *H. recurvata*, was common. So it may be, in some cases at least, that

the nighttime level may be the low point of the 24 hour period, and the peaks the result of inducement to even greater activity. But most species generally only appeared flying after sunset. Some lack of response to the Mercury vapour light may explain part of the abrupt rise and fall in evening and morning, but as the change from twilight to full sun-light, or the reverse, is gradual, so also should the decrease in attractiveness of the light be gradual, which it is not. But from just what level of a flying population the evening rise, for example, is abrupt, cannot be deduced here. Considering the day activity of some species, the abrupt rise may be explained by the light gradually being effective and the flying population already at a high level. However, the peaks, as such, above this level can only be regarded as natural phenomena in themselves, due to the gradual decrease after the evening peak and the slight rise preceeding the morning peak.

Another point in favour of the 'natural' peak is the spectral quality of the light source. The exact quality is not known (no data comes with the bulbs), but the light is known to be very rich in UV wavelengths; much more so than daylight (it was considered undesirable to look at the bulb for any length of time for fear of eye damage). Trichoptera can detect UV light and probably, if they are similar to most insects (Hocking, 1964), they detect UV far beyond wavelengths found in natural environments and are attracted to it. Why, therefore, can they not detect these wavelengths in the daytime and be attracted to the trap? They probably could, if flying. In a way therefore the use of a Mercury vapour light bulb may actually provide a preliminary guide as to whether

or not the pattern is natural. It is proposed that, in its essential features, it is,for those species which compose it.

Lewis and Taylor (1965) (who examined non-attractive trapping records only) indicate that there are day, night and crepuscular flyers in the Trichoptera, the day flyers being predominantly Leptoceridae, Hydropsychidae and Hydroptilidae; just the three families which occurred most often, in numbers and species, in the Montreal night catches. Their comments on the characteristics of day flying Trichoptera are rather dubious as they have little to say regarding night flyers. This is undoubtedly due to a lack of non-attractive night trapping records. I have found from experience that it is difficult to hand net Trichoptera after about one half hour after sunset. All in all, it seems best to reserve conclusions on the identity and characteristics of night and day flying Trichoptera until more records are available.

SUMMARY

a). In conjunction with a project to study the potential nuisance value of aquatic insects at the site for the 1967 Montreal World's Fair, on Ile Ste. Hélène in the St. Lawrence River opposite Montreal, Que., the nocturnal pattern of arrival of Trichoptera at artificial light was examined.

b). Catches were made using parts of a Robinson insect light trap, with a mercury vapour light bulb which emits light rich in ultra-violet wavelengths. One hour catch periods were used to study the entire arrival pattern, entailing the use of an automatic device, the LaFrance trap, for changing catch containers once hourly. Ten minute catch periods were used to examine the evening peak in detail, containers being changed manually.

c). All Trichoptera taken were determined to species and sex and the condition of the females (gravid or non-gravid) was determined.

d). Seventy eight species were determined, one of which is a new species, and two other doubtful forms, females, were noted. Thirty one genera and thirteen families are represented. Seasonal distributions are summarised. Total numbers of each species for the summer are presented, then broken down to numbers of each sex and female condition. Summer sex ratios are determined. Seven species are selected for further detailed examination of data.

e). The activity at night, of the Trichoptera as a whole (total numbers, all species) proved to be bimodal with, intrinsically,

a main flight at dusk and a much smaller flight at dawn. That is, a sharp upsurge occurs just after sunset, to a distinct peak, followed by a gradually decreasing decline in numbers till, just before dawn, a smaller peak occurs, followed by a sharp drop-off in numbers. The 10 min. catches demonstrated that the evening peak upsurge begins just prior to civil twilight, and it is surmised that the morning peak terminates just after civil twilight.

f). All 7 selected species showed the bimodal pattern, and essentially follow the total numbers pattern on any given night.

g). The sex ratios and percentages of gravid females showed little major deviation in either direction, from a constant ratio throughout the night.

h). Temperature and wind are the prime factors controlling the total catch on any given night, and also in producing fluctuations within the pattern itself. Neither relative humidity nor saturation deficit seemed to be of any significance, at the values experienced. A differential effect of wind on flight, depending on species size, is shown.

i). The possibility of the pattern at light being a natural pattern of flight activity is examined. It is concluded that the peaks, and that part of the pattern between, are natural. Difficulty arises in determining if the upsurge before the evening peak is from the zero level, or from an already existing greater level of daytime flight activity. The same difficulty arises when considering the level to which the morning peak falls away. It is here especially that

the trapping method proves troublesome due to the use of a response on the part of the insects to an attraction, and yet provides a possible answer because of the nature of the attraction. It is concluded that the entire arrival pattern is essentially a fair reflection of an intrinsically occurring pattern of activity.

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APPENDICES

APPENDIX A

TOTAL NUMBERS OF TRICHOPTERA TAKEN AT ILE STE. HÉLÈNE, MONTREAL

PER I HR. CATCH PERIOD PER NIGHT, SUMMER 1964

CATCH NIGHT / CATCH NO.	13-14/6/64	16-17/6/64	17-18/6/64	27-28/6/64	1- 2/7/64	4- 5/7/64	6- 7/7/64	13-14/7/64	18-19/7/64	23-24/7/64	1- 2/8/64	3- 4/8/64	8- 9/8/64	12-13/8/64	19-20/8/64	25-26/8/64
1	179	1	19	21	21	26	6	41	39	67	285	47	19	39	2138	1413
2	1665	6	2510	3208	7532	562	2087	3261	374	2361	1959	707	1474	1795	3563	28215
3	740	9	621	291	9390	193	1154	783	534	1214	6218	320	412	664	856	568
4	164	1	77	276	2535	280	590	261	518	508	3288	256	173	288	169	161
5	1288	-	44	273	1210	248	295	178	1411	310	685	223	32	91	340	140
6	1828	-	14	319	1849	173	243	121	15688	129	820	125	14	4	877	63
7	512	-	13	152	3237	1341	218	123	14082	222	794	26	10	12	468	58
8	230	1	10	50	1072	851	119	119	25046	223	3673	28	3	5	268	54
9	290	-	12	26	921	144	57	160	8182	475	1198	95	3	6	1822	80
10	4	-	2	2	12	4	3	-	159	14	1563	42	4	7	378	69
11	1	-	1	5	3	3	6	-	47	3	28	1	2	2	32	95
12	-	-	2	2	7	1	3	-	20	1	19	1	5	1	-	30

APPENDIX B

METEOROLOGICAL DATA FOR EACH NIGHT ON WHICH TRAPPING WAS CARRIED ON AT ILE STE. HÉLÈNE, MONTREAL, SUMMER 1964

Catch Night	13-14/vi				16-17/vi				17-18/vi			
Catch Period	T.°F.	R.H.*	S.D.**	Wind	T.°F.	R.H.	S.D.	Wind	T.°F.	R.H.	S.D.	Wind
1	73.0	64	.29	-	57.5	38	.30	21	63.5	29	.42	6
2	73.0	74	.21	-	57.0	40	.30	21	63.0	32	.39	7
3	72.5	73	.22	-	56.0	44	.25	19	62.0	36	.36	7
4	69.5	75	.18	-	55.0	42	.25	20	61.0	39	.33	7
5	69.5	82	.13	-	54.0	43	.24	22	60.0	42	.30	9
6	70.0	78	.16	-	54.0	43	.24	22	60.0	46	.28	8
7	69.0	88	.08	-	53.5	42	.24	21	60.0	47	.27	8
8	68.0	86	.10	-	53.5	37	.26	19	59.0	49	.25	10
9	68.0	78	.15	-	55.5	41	.26	16	60.0	50	.26	9

* R.H. = Relative Humidity; ** S.D. = Saturation Deficit, in inches of mercury.

Appendix B - continued

Catch Night	27-28/vi				1-2/vii				4-5/vii			
Catch Period	T.^{o}F.	R.H.	S.D.	Wind	T.^{o}F.	R.H.	S.D.	Wind	T.^{o}F.	R.H.	S.D.	Wind
1	75.0	34	.57	10	84.0	36	.74	4	70.0	55	.33	12
2	73.0	35	.52	7	79.0	56	.44	2	69.0	52	.34	11
3	72.0	37	.49	9	78.0	54	.44	2	68.0	60	.27	11
4	70.0	40	.44	8	78.0	56	.42	3	67.5	69	.21	8
5	67.5	45	.38	7	76.0	53	.44	4	67.0	73	.18	8
6	67.0	45	.36	6	74.0	59	.34	3	66.0	76	.15	8
7	66.0	50	.32	4	72.0	62	.30	0	66.0	80	.13	7
8	62.0	54	.26	5	71.0	67	.25	5	66.0	89	.10	5
9	62.0	53	.26	4	71.0	70	.23	4	66.0	79	.13	6

Appendix B - continued

Catch Night	6-7/vii				13-14/vii				18-19/vii			
Catch Period	T°F.	R.H.	S.D.	Wind	T°F.	R.H.	S.D.	Wind	T°F.	R.H.	S.D.	Wind
1	72.5	72	.23	2	71.0	85	.11	2	89.0	43	.78	24
2	72.0	62	.30	4	70.0	82	.13	1	88.0	42	.77	25
3	73.0	65	.28	2	69.5	81	.14	3	87.0	45	.70	25
4	69.5	74	.19	2	69.5	84	.12	3	86.0	49	.63	23
5	68.0	74	.18	1	69.0	89	.08	2	85.0	52	.58	14
6	67.5	78	.15	3	68.5	88	.08	2	85.0	56	.53	8
7	66.0	86	.10	4	68.0	88	.08	2	84.0	61	.45	5
8	64.0	89	.07	2	68.0	88	.08	2	83.0	64	.40	3
9	64.0	88	.07	6	68.0	88	.08	1	83.0	70	.34	1

Appendix B - continued

Catch Night	23-24/vii				1-2/viii				3-4/viii			
Catch Period	T.°F.	R.H.	S.D.	Wind	T°F.	R.H.	S.D.	Wind	T°F.	R.H.	S.D.	Wind
1	77.0	70	.28	14	71.0	38	.47	4	72.0	38	.48	4
2	75.0	73	.23	17	69.5	39	.45	2	69.0	46	.38	4
3	70.0	77	.17	18	68.0	44	.38	2	67.0	52	.32	4
4	67.0	81	.13	18	66.0	49	.32	3	65.0	57	.28	4
5	64.0	80	.12	18	63.0	50	.29	2	65.0	56	.27	3
6	64.0	79	.13	17	61.0	50	.27	2	64.0	55	.27	2
7	64.0	80	.12	17	61.0	53	.25	2	63.0	58	.24	3
8	63.0	80	.12	16	59.0	48	.26	6	61.0	63	.20	2
9	62.0	80	.11	15	58.0	50	.24	3	60.0	66	.18	2
10					57.0	54	.21	8	59.0	68	.16	2

Appendix B - continued

Catch Night	8-9/viii				12-13/viii			
Catch Period	T.°F.	R.H.	S.D.	Wind	T.°H.	R.H.	S.D.	Wind
1	70.5	60	.30	11	57.0	53	.22	17
2	70.0	58	.31	14	56.5	57	.20	15
3	69.0	59	.29	9	56.0	60	.18	14
4	68.0	64	.25	12	55.5	62	.17	12
5	67.0	64	.24	10	55.0	62	.16	15
6	63.0	65	.20	11	54.0	62	.16	17
7	62.5	66	.20	11	53.5	62	.16	20
8	61.5	68	.18	13	52.5	67	.13	19
9	61.0	69	.17	13	52.0	66	.13	20
10	62.0	70	.17	13	52.5	70	.12	16

Appendix B - continued

Catch Night	19-20/viii				25-26/viii			
Catch period	$T^{o}F.$	R.H.	S.D.	Wind	$T^{o}F.$	R.H.	S.D.	Wind
1	65.0	38	.38	8	73.0	58	.34	9
2	63.5	39	.36	9	69.0	60	.28	9
3	63.0	42	.33	9	67.0	54	.30	19
4	62.0	46	.30	8	67.0	70	.20	19
5	61.0	50	.27	8	67.0	76	.16	18
6	60.0	50	.26	7	67.0	79	.14	15
7	60.0	52	.25	6	67.0	79	.14	14
8	60.0	51	.25	6	66.0	76	.15	15
9	60.0	49	.26	5	65.0	71	.18	14
10	60.0	52	.25	6	64.0	72	.17	14

APPENDIX C

TOTAL NUMBERS OF TRICHOPTERA TAKEN AT ILE STE. HÉLÈNE, MONTREAL PER 10 MIN. CATCH PERIOD PER NIGHT, SUMMER 1964

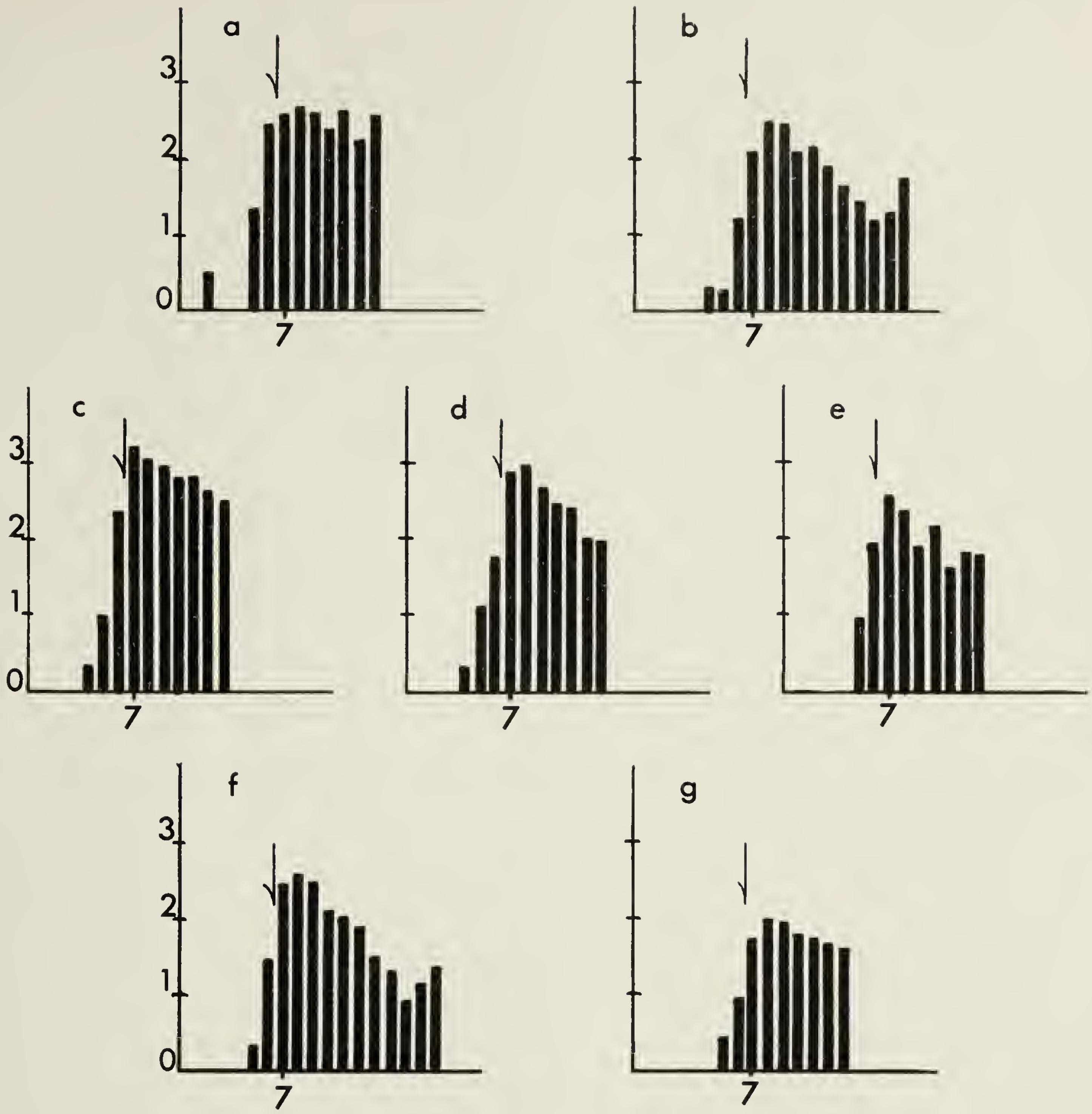
Catch Night / Catch Period	2-3/7/64	7-8/7/64	14-15/7/64	19-20/7/64	24-25/7/64	6-7/8/64	13-14/8/64	23-24/8/64	26-27/8/64	30-31/8/64
1	-	-	1	-	1	-	-	-	1	-
2	1	-	1	-	-	-	-	1	2	-
3	1	-	1	1	-	-	-	3	-	-
4	7	2	-	11	1	14	5	10	4	1
5	39	31	2	135	6	111	33	13	51	11
6	181	82	44	290	122	261	27	168	606	277
7	528	262	568	524	377	484	19	408	3372	1634
8	472	604	1663	1026	417	571	3	169	3034	2742
9	407	812	714	1202	624	277	2	174	2156	1678
10	486	678	592	871	994	162		309	1524	1253
11	429	318	970	647	684	202		309	2091	1079
12	376	333	809	602	635	245		164	1448	1429
13	334	266	676	474	961	216		215	1291	1784
14	223	130	354	389	808					
15	264	65	299		1271					
16	237	44	257		755					
17	173	48			685					
18	172	145			644					
19	169									

APPENDIX D

CORRECT (DOMINION OBSERVATORY) AND INCORRECT (DEPT. OF AGRICULTURE) TIMES[1] OF SUNSET AT ILE STE. HÉLÈNE MONTREAL, FOR CERTAIN NIGHTS OF 1964 - VALUES USED ARE UNDERLINED

NIGHT	CORRECT SUNSET	INCORRECT SUNSET	ERROR (min.)	NIGHT	CORRECT SUNSET	INCORRECT SUNSET	ERROR (min.)
13-14/6/64	<u>8.45</u>	8.43	-2	18-19/7/64	8.38	<u>8.39</u>	+1
16-17/6/64	<u>8.45</u>	8.44	-1	23-24/7/64	8.33	<u>8.34</u>	+1
17-18/6/64	<u>8.45</u>	8.45	-	1- 2/8/64	8.22	<u>8.24</u>	+2
27-28/6/64	<u>8.48</u>	8.47	-1	3- 4/8/64	8.19	<u>8.22</u>	+3
1- 2/7/64	<u>8.47</u>	<u>8.47</u>	-	8- 9/8/64	8.13	<u>8.15</u>	+2
4- 5/7/64	<u>8.46</u>	<u>8.46</u>	-	12-13/8/64	8.06	<u>8.09</u>	+3
6- 7/7/64	8.45	<u>8.46</u>	+1	19-20/8/64	<u>7.55</u>	7.57	+2
13-14/7/64	8.41	<u>8.42</u>	+1	25-26/8/64	<u>7.44</u>	7.47	+3

1. Eastern Daylight Saving Time.



Appendix E - Graphs, for each of 7 selected species taken at Ile Ste. Hélène, Montreal, 1964, illustrating the initiation of the evening peak of numbers arriving at an ultra-violet light trap. Ordinates in logs.; abscissae in 10 min. periods, log(n + 1) values plotted at the period mid-points. Civil twilight indicated by the arrows. The species and nights are as follows : a) Hydroptila spatulata, 19-20/vii ; b) Cheumatopsyche speciosa, 14-15/vii ; c) Protoptila maculata, 26-27/viii ; d) Hydropsyche recurvata, 26-27/viii ; e) Psychomyia flavida, 30-31/viii ; f) Athripsodes cancellatus, 14-15/vii ; Athripsodes tarsipunctatus, 19-20/vii .